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THE READJUSTMENT OF CERTAIN UNSTABLE ATMOSPHERIC SYSTEMS UNDER CONSERVATION OF VORTICITY [1]

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In his memoir "On the Energy of Storms", Margules devised methods for the calculation of the maximum kinetic energy of atmospheric systems that can result from the rearrangement of two air masses of differing properties, from an initial unstable arrangement to one possessing stability. Although his results show that the kinetic energy made available by these processes is sufficient to account for observed wind velocities, no attempt was made by Margules to deduce the probable distribution of this kinetic energy within the air masses which comprise the systems studied. In order to secure some idea of the character that this distribution might be expected to assume, a problem similar in certain respects to some of the cases treated by Margules will be formulated and solved making use of a principle which may be alluded to as that of conservation of absolute vorticity. Because of the great complexities which arise in an attempt to deal with a compressible atmosphere, attention will be confined to a system composed of two homogeneous and incompressible fluids of slightly differing densities. It will also be assumed in the treatment that all frictional effects are absent.

Let it be supposed that in the initial state two masses of fluid of differing densities lie side by side, at rest relative to the earth, separated by a vertical plane as in figure 1, with the lighter fluid to the right. The horizontal layer thus formed is considered as being of uniform thickness and extending an infinite distance to the right and to the left. The problem for which a solution is sought may be stated as follows: Assuming no mixing of the fluids, what will be the shape of the free surface and of the internal boundary, if the system is allowed to come infinitely slowly to equilibrium, taking into consideration the effect of the earth's rotation on all the motions involved in the readjustment? Also, what will be the distribution of velocities generated by the action of pressure gradients and of Coriolis forces within each mass of fluid?

In outline the changes that take place upon the transition to a state of equilibrium may be described as follows: A portion of the denser fluid located in the region A in the initial state will tend to be displaced to the right. Since this displacement is accompanied by a Coriolis force acting at right angles to the direction of motion, a transverse horizontal velocity will be generated in this portion of fluid. In a steady state this velocity must be accompanied by a gradient of pressure which in this case is supplied by a mutual adjustment of the slope of the free surface and of the internal boundary separating the liquids. Likewise a portion of the lighter fluid originally situated at B will tend to move to the left, bringing about a transverse velocity in the opposite sense. The requisite pressure gradient in this case is produced by the deformation of the free surface alone.

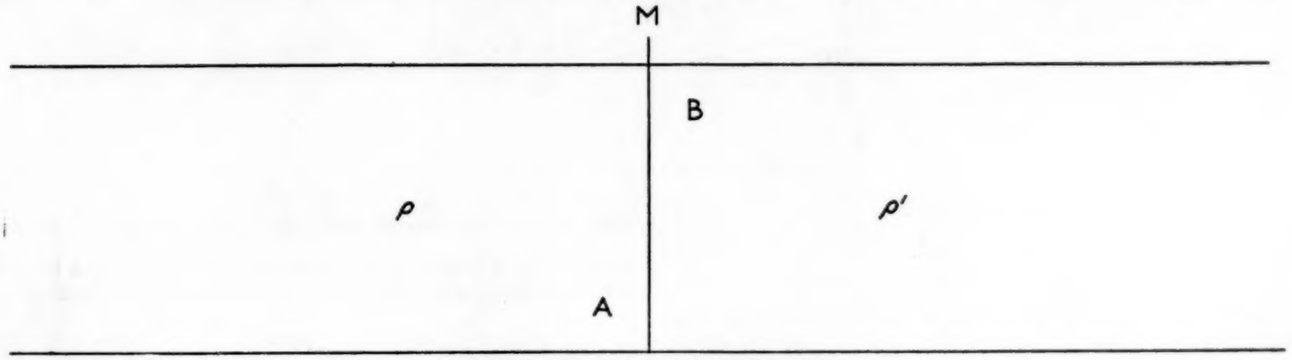

FIGURE 1.—Two fluid masses in the initial state.

Due to the fact that continuity of depth must be preserved throughout the layer, it must be assumed that some lateral movement with resulting transverse velocities must occur in the regions farther to the left and to the right, decreasing to zero at great distances from the original discontinuity. It is now possible to schematically represent the final state as in figure 2.

It thus appears that for the purpose of analysis the system may be divided into three regions, regions I and III in figure 2 consisting of a single layer, while region II consists of two superimposed layers. The distances c and a are to be obtained as a result of the investigation. In the above diagram the positive y direction is taken to the left and the positive x direction as perpendicular to the plane of the figure away from the reader, while the origin is located

[1] This paper is a report on an investigation which has been conducted at the Massachusetts Institute of Technology in cooperation with the Weather Bureau under the Bankhead-Jones Special Research Fund.

at O. For convenience, the diagram is taken in the plane of a meridian with the positive y direction extending northward. In the Northern Hemisphere this leads to easterly winds in the regions marked E and westerly winds in the region marked W. Since the equations of motion used in meteorology are independent of the azimuthal orientation of the axes, this choice of coordinates will not produce any lack of generality in the results.

Restricting our attention for the present to region I, let it be assumed that a column of fluid which in the initial state was located at a point y_0^{I} and had a width dy_0^{I} and a height D_0 is now located at a point y, has a width dy and a height D^{I}. The principle of continuity of mass gives

$$\rho D_0 dy_0^{\mathrm{I}} = \rho D^{\mathrm{I}} dy \tag{1}$$

or

$$D^{\mathrm{I}} = D_0 \frac{dy_0^{\mathrm{I}}}{dy} \tag{2}$$

where g is the acceleration of gravity and ρ is the density. By differentiation,

$$\frac{dD^{\mathrm{I}}}{dy} = D_0 \frac{d^2 y_0^{\mathrm{I}}}{dy^2} \tag{3}$$

Indicating velocities in the x direction by u^{I} and velocities in the y direction by v the equation of motion for the transverse velocity of the element, since no net external forces are present, is

$$\frac{du^{\mathrm{I}}}{dt} = fv = f\frac{dy}{dt}, \tag{4}$$

where f is the Coriolis parameter $2\,\Omega\,sin\phi$. Integrating between the limits y_0^{I} and y

$$u^{\mathrm{I}} = f(y - y_0^{\mathrm{I}}). \tag{5}$$

This implies that the velocities are constant with elevation and therefore the pressure gradients must be independent of elevation—a result which agrees with hydrostatical considerations.

Since a steady state is assumed, in the final condition the gradient wind equation must be fulfilled. For straight line flow, this will be

$$0 = -fu^{\mathrm{I}} - \frac{1}{\rho}\frac{\partial p_g}{\partial y}. \tag{6}$$

In the above p_g may be taken as the pressure at the surface, for which the value $g\rho D^{\mathrm{I}}$ may be substituted. Substituting also for u^{I} from (5),

$$0 = -f^2(y - y_0^{\mathrm{I}}) - g\frac{dD^{\mathrm{I}}}{dy}. \tag{7}$$

Substituting for $\frac{dD^{\mathrm{I}}}{dy}$ from (3),

$$0 = (y - y_0^{\mathrm{I}}) + \frac{gD_0}{f^2}\frac{d^2 y_0^{\mathrm{I}}}{dy^2}. \tag{8}$$

Since the quantities g, D_0 and f are considered constant in this whole discussion and since the factor $\frac{gD_0}{f^2}$ recurs frequently, a quantity λ having the dimensions of a length will be defined as follows, and substituted in the equations:

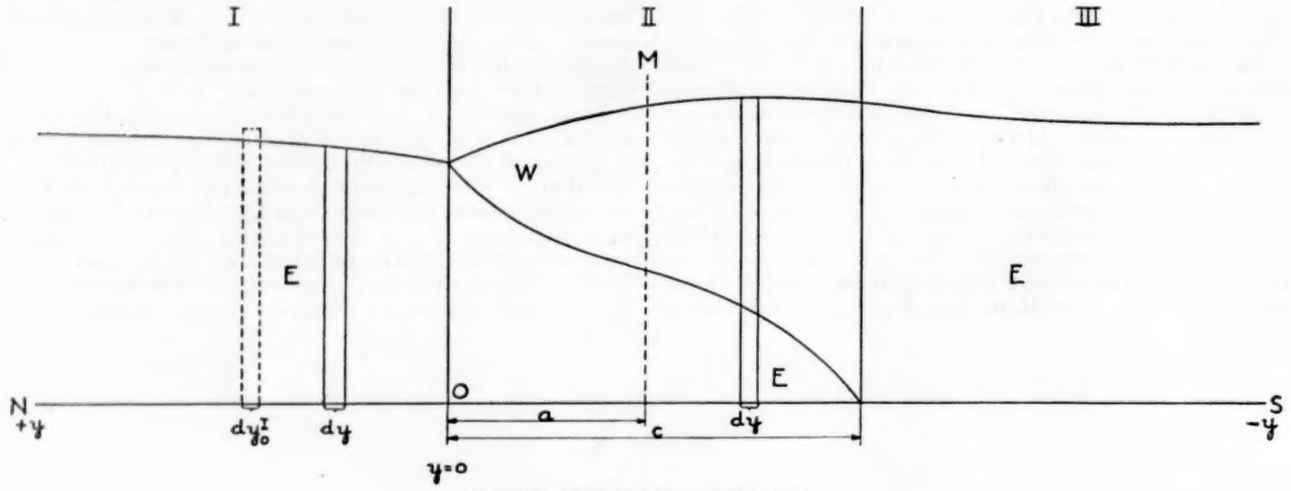

FIGURE 2.—Schematic diagram of the final state.

$$\lambda = \frac{\sqrt{gD_0}}{f} \tag{9}$$

Equation (8) now becomes,

$$\frac{d^2 y_0^{\mathrm{I}}}{dy^2} + \frac{1}{\lambda^2}(y - y_0^{\mathrm{I}}) = 0. \tag{10}$$

The solution of this equation is easily shown to be

$$y_0^{\mathrm{I}} = y + Q^{\mathrm{I}} e^{\frac{\lambda - y}{\lambda}} + Q^{\mathrm{III}} e^{\frac{y}{\lambda}} \tag{11}$$

In this equation Q^{I} and Q^{III} are constants of integration which must be fixed by boundary conditions while e is the Napierian base. Obviously Q^{III} must be zero in region I since the liquid is to be undisturbed at great distances to the left. This is only possible if $y^{\mathrm{I}}{}_0 = y$ for large values of y. The value of Q^{I} on the other hand cannot be determined at this point, but must be evaluated later, simultaneously with the determination of other similar integration constants for the remaining two regions. The fundamental equation for region I, giving the lateral change of position of a particle from the initial to the final state may be written,

$$y_0^{\mathrm{I}} = y + Q^{\mathrm{I}} e^{-\frac{y}{\lambda}} \tag{12}$$

From this equation the velocity distribution may be obtained by the aid of equation (5) and is found to be,

$$u^{I}=-fQ^{I}e^{-\frac{y}{\lambda}} \tag{13}$$

By differentiating (12) with respect to y and combining the result with (2) an expression for the shape of the free surface results,

$$D^{I}=D_0\left[1-\frac{1}{\lambda}Q^{I}e^{-\frac{y}{\lambda}}\right] \tag{14}$$

Considering now the conditions in region III, an exactly analogous line of reasoning may be followed as was used above, and an equation comparable to (11) may be set down,

$$y_0^{III}=y+Q^{I}e^{-\frac{y}{\lambda}}+Q^{III}e^{\frac{y}{\lambda}}. \tag{15}$$

It is clear, however, that now the constant Q^{I} must be zero since the fluid is not disturbed at great distances to the right, and the fundamental equation for region III becomes

$$y_0^{III}=y+Q^{III}e^{\frac{y}{\lambda}}. \tag{16}$$

The constant Q^{III} will be evaluated later.

Expressions for the velocity distribution and for the shape of the free surface may be written immediately as in the case of region I. These are respectively,

$$u^{III}=-fQ^{III}e^{\frac{y}{\lambda}}, \tag{17}$$

and

$$D^{III}=D_0\left[1+\frac{1}{\lambda}Q^{III}e^{\frac{y}{\lambda}}\right]. \tag{18}$$

Turning our attention to region II, the situation is more complicated due to the presence of a double layer. Retaining the convention of indicating quantities referring to the initial state by the subscript zero, and designating quantities applying to the upper layer by primes, an elemental vertical column extending from the surface to the top will now be considered. Corresponding to equation (1), which specified the requirement of continuity of mass, there are now two such equations:

$$\rho' D_0' dy_0^{II'}=\rho' D^{II'}dy, \tag{19}$$

for the upper layer and

$$\rho D_0 dy_0^{II}=\rho D^{II}dy \tag{20}$$

for the lower layer. In these two equations a distinction is made between the quantities D_0 and D_0'. Although according to the statement of the problem made previously these are equal, this simplification will not be made at this point, in view of the possible application of the equations derived to more general problems than the one dealt with at present. Solving (19) and (20) for the depths in the final state,

$$D^{II'}=D_0'\frac{dy_0^{II'}}{dy}, \tag{21}$$

and

$$D^{II}=D_0\frac{dy_0^{II}}{dy} \tag{22}$$

Differentiating the above with respect to y

$$\frac{dD^{II'}}{dy}=D_0'\frac{d^2y_0^{II'}}{dy^2}, \tag{23}$$

and

$$\frac{dD^{II}}{dy}=D_0\frac{dy_0^{II}}{dy^2}. \tag{24}$$

Corresponding to equation (5) there are two expressions for velocity, namely

$$u^{II'}=f(y-y_0^{II'}), \tag{25}$$

and

$$u^{II}=f(y-y_0^{II}). \tag{26}$$

We also have two gradient wind equations:

$$0=-fu^{II'}-\frac{1}{\rho'}\frac{\partial p_g'}{\partial y}, \tag{27}$$

for the upper layer and

$$0=-fu^{II}-\frac{1}{\rho}\frac{\partial p_g}{\partial y} \tag{28}$$

for the lower. A question now arises as to the interpretation of p_g' in equation (27). Since (27) involves only the gradient of pressure and not the absolute value of the pressure, the derivative appearing may be evaluated by forming an expression for the pressure distribution along any level surface in the upper layer, and differentiating. This can be done conveniently by considering the pressure at a level surface situated at an arbitrary elevation Z. Thus

$$p_g'=g\rho'(D^{II'}+D^{II}-Z). \tag{29}$$

Differentiating and changing to ordinary derivatives,

$$\frac{dp_g'}{dy}=g\rho'\left(\frac{dD^{II'}}{dy}+\frac{dD^{II}}{dy}\right). \tag{30}$$

For the lower layer,

$$p_g=g\rho' D^{II'}+g\rho D^{II} \tag{31}$$

and

$$\frac{dp_g}{dy}=g\rho'\frac{dD^{II'}}{dy}+\frac{g\rho dD^{II}}{dy}. \tag{32}$$

Substituting in equations (27) and (28) from (25) and (26) and also from (30) and (32)

$$0=-f^2(y-y_0^{II'})-g\left[\frac{dD^{II'}}{dy}+\frac{dD^{II}}{dy}\right], \tag{33}$$

and

$$0=-f^2(y-y_0^{II})-\frac{g}{\rho}\left[\rho'\frac{dD^{II'}}{dy}+\frac{\rho dD^{II}}{dy}\right] \tag{34}$$

Substituting in the above two equations for the derivatives of the depths the values given by (23) and (24), we get:

$$0=-f^2(y-y_0^{II'})-g\left[D_0'\frac{d^2y_0^{II'}}{dy^2}+D_0\frac{d^2y_0^{II}}{dy^2}\right] \tag{35}$$

and

$$0=-f^2(y-y_0^{II})-g\left[D_0'\frac{\rho'}{\rho}\frac{d^2y_0^{II'}}{dy^2}+D_0\frac{d^2y_0^{II}}{dy^2}\right] \tag{36}$$

We thus finally have a pair of second order simultaneous differential equations involving the single independent

variable y and two dependent variables $y_0^{II'}$ and y_0^{II}, which must be solved. Customary methods of separating the dependent variables lead to two fourth order equations whose solutions contain eight constants of integration. Rather than to pursue this course the separation of variables will be effected as follows: [1] Let the first equation be multiplied by an undetermined constant factor α, so that the equations have the form,

$$0=-f^2(\alpha y-\alpha y_0^{II'})-g\left[\alpha D_0'\frac{d^2y_0^{II'}}{dy^2}+\alpha D_0\frac{d^2y_0^{II}}{dy^2}\right]. \quad (37)$$

$$0=-f^2(y-y_0^{II})-g\left[D_0'\frac{\rho'}{\rho}\frac{d^2y_0^{II'}}{dy^2}+D_0\frac{d^2y_0^{II}}{dy^2}\right]. \quad (38)$$

Adding,

$$0=f^2[y_0^{II}+\alpha y_0^{II'}-(1+\alpha)y]$$
$$-g\left[\left(\frac{\rho'}{\rho}+\alpha\right)D_0'\frac{d^2y_0^{II'}}{dy^2}+(1+\alpha)D_0\frac{d^2y_0^{II}}{dy}\right]. \quad (39)$$

Rearranging,

$$0=f^2[y_0^{II}+\alpha y_0^{II'}-(1+\alpha)y]$$
$$-gD_0(1+\alpha)\frac{d^2}{dy^2}\left[y_0^{II}+\frac{\frac{\rho'}{\rho}+\alpha}{1+\alpha}\frac{D_0'}{D_0}y_0^{II'}\right]. \quad (40)$$

Let the value of α be now defined so as to make the coefficient of $y_0^{II'}$ in the first brackets equal to the coefficient of $y_0^{II'}$ in the second brackets. This gives the relation

$$\alpha=\frac{\rho'+\rho\alpha}{\rho(1+\alpha)}\frac{D_0'}{D_0}, \quad (41)$$

which has two roots,

$$\alpha_1=-\frac{D_0-D_0'}{2D_0}+\frac{1}{2}\sqrt{\frac{(D_0-D_0')^2}{D_0^2}+\frac{4\rho'D_0'}{\rho D_0}} \quad (42)$$

and

$$\alpha_2=-\frac{D_0-D_0'}{2D_0}-\frac{1}{2}\sqrt{\frac{(D_0-D_0')^2}{D_0^2}+\frac{4\rho'D_0'}{\rho D_0}}. \quad (43)$$

Let two dependent variables A_1 and A_2 be defined by the following:

$$A_1=y_0^{II}+\alpha_1y_0^{II'}, \quad (44)$$

$$A_2=y_0^{II}+\alpha_2y_0^{II'}. \quad (45)$$

Introducing these into (40) two equations in which the variables are separated are obtained:

$$0=A_1-(1+\alpha_1)y-\frac{gD_0}{f^2}(1+\alpha_1)\frac{d^2A_1}{dy^2}; \quad (46)$$

$$0=A_2-(1+\alpha_2)y-\frac{gD_0}{f^2}(1+\alpha_2)\frac{d^2A_2}{dy^2}. \quad (47)$$

Introducing λ and rearranging,

$$\frac{d^2A_1}{dy^2}-\frac{1}{(1+\alpha_1)\lambda^2}[A_1-(1+\alpha_1)y]=0; \quad (48)$$

$$\frac{d^2A_2}{dy^2}-\frac{1}{(1+\alpha_2)\lambda^2}[A_2-(1+\alpha_2)y]=0. \quad (49)$$

[1] This procedure was suggested to the writer by Prof. C. G. Rossby.

The solutions of (48) and (49) may be set down immediately in the form

$$A_1=(1+\alpha_1)y+K_1e^{\kappa_1y}+Q_1e^{-\kappa_1y} \quad (50)$$

and

$$A_2=(1+\alpha_2)y+K_2e^{\kappa_2y}+Q_2e^{-\kappa_2y}, \quad (51)$$

in which K_1, K_2, Q_1, and Q_2 are constants of integration and κ_1 and κ_2 are given by

$$\kappa_1=\frac{1}{\lambda\sqrt{1+\alpha_1}}; \quad (52)$$

$$\kappa_2=\frac{1}{\lambda\sqrt{1+\alpha_2}} \quad (53)$$

Reverting to the original dependent variables, $y_0^{II'}$ and y_0^{II}, we have from (44) and (45)

$$A_1-A_2=\alpha_1y_0^{II'}-\alpha_2y_0^{II'}=y_0^{II'}(\alpha_1-\alpha_2), \quad (54)$$

and

$$y_0^{II'}=\frac{A_1-A_2}{\alpha_1-\alpha_2}. \quad (55)$$

Similarly,

$$\alpha_2A_1-\alpha_1A_2=\alpha_2y_0^{II}-\alpha_1y_0^{II}=y_0^{II}(\alpha_2-\alpha_1), \quad (56)$$

and

$$y_0^{II}=\frac{\alpha_2A_1-\alpha_1A_2}{\alpha_2-\alpha_1}. \quad (57)$$

Substituting in (55) and (57) from (50) and (51),

$$y_0^{II'}=y+\frac{1}{\alpha_1-\alpha_2}\left[K_1e^{\kappa_1y}-K_2e^{\kappa_2y}+Q_1e^{-\kappa_1y}-Q_2e^{-\kappa_2y}\right]; \quad (58)$$

and

$$y_0^{II}=y+\frac{1}{\alpha_2-\alpha_1}[\alpha_2K_1e^{\kappa_1y}-\alpha_1K_2e^{\kappa_2y}+\alpha_2Q_1e^{-\kappa_1y}-\alpha_1Q_2e^{-\kappa_2y}]. \quad (59)$$

Let the simplification now be made that $D'_0=D_0$. From (42) and (43) it is seen that

$$\alpha_1=+\sqrt{\frac{\rho'}{\rho}}; \quad (60)$$

$$\alpha_2=-\sqrt{\frac{\rho'}{\rho}}. \quad (61)$$

In other words we may say that

$$\alpha_1=-\alpha_2=\alpha=\sqrt{\frac{\rho'}{\rho}}. \quad (62)$$

The final form of the fundamental equations for region II thus becomes,

$$y_0^{II'}=y+\frac{1}{2\alpha}[K_1e^{\kappa_1y}-K_2e^{\kappa_2y}+Q_1e^{-\kappa_1y}-Q_2e^{-\kappa_2y}], \quad (63)$$

$$y_0^{II}=y+\frac{1}{2}[K_1e^{\kappa_1y}+K_2e^{\kappa_2y}+Q_1e^{-\kappa_1y}+Q_2e^{-\kappa_2y}]. \quad (64)$$

By the aid of (25) and (26) expressions for the velocities in the two layers are obtained:

$$u^{II'}=-\frac{f}{2\alpha}[K_1e^{\kappa_1y}-K_2e^{\kappa_2y}+Q_1e^{-\kappa_1y}-Q_2e^{-\kappa_2y}], \quad (65)$$

$$u^{II}=-\frac{f}{2}[K_1e^{\kappa_1y}+K_2e^{\kappa_2y}+Q_1e^{-\kappa_1y}+Q_2e^{-\kappa_2y}]. \quad (66)$$

By means of (22) and (64) the position of the internal boundary may be specified:

$$D^{II}=D_0\left[1+\frac{1}{2}(K_1\kappa_1 e^{\kappa_1 y}+K_2\kappa_2 e^{\kappa_2 y}-Q_1\kappa_1 e^{-\kappa_1 y}-Q_2\kappa_2 e^{-\kappa_2 y})\right]. \quad (67)$$

The thickness of the upper layer can be obtained in a similar manner from (21) and (63):

$$D^{II'}=D_0\left[1+\frac{1}{2\alpha}(K_1\kappa_1 e^{\kappa_1 y}-K_2\kappa_2 e^{\kappa_2 y}-Q_1\kappa_1 e^{-\kappa_1 y}+Q_2\kappa_2 e^{-\kappa_2 y})\right]. \quad (68)$$

The shape of the free surface is given by the sum of $D^{II'}$ and D^{II} for each value of y.

Having derived the fundamental equations (12) and (16) for regions I and III, respectively, and (63) and (64) for region III, it is next necessary to determine simultaneously the six integration constants Q^I, Q^{III}, K_1, K_2, Q_1, and Q_2 and also the constants c and a. In order to accomplish this it is necessary to have eight equations not involving the independent and dependent variables. By examining the requirements at the two vertical boundaries separating the three regions it will be seen that there exist exactly eight independent boundary conditions which can be interpreted in the form of the eight required equations.

Taking first the vertical at $y=0$ in figure 2, the fluid in the upper layer of region II at this point originally was located at the discontinuity, hence the condition exists that when

$$\left.\begin{matrix} y=0 \\ y_0^{II'}=-a \end{matrix}\right\}. \quad (69)$$

Also it was assumed that at this point the thickness of the upper layer of region II becomes zero, hence according to (21) when

$$\left.\begin{matrix} y=0 \\ \dfrac{dy_0^{II'}}{dy}=0 \end{matrix}\right\}. \quad (70)$$

Since the fluid in region I is in contact with the fluid in the lower layer of region II at $y=0$, there must be continuity in the displacements at this point so that

$$\left.\begin{matrix} y=0 \\ y_0^{I}=y_0^{II} \end{matrix}\right\}. \quad (71)$$

Finally, since the depth of the fluid in the lower layer of region II must be the same as that of region I at this point, we have from (2) and (22)

$$\left.\begin{matrix} y=0 \\ \dfrac{dy_0^{I}}{dy}=\dfrac{dy_0^{II}}{dy} \end{matrix}\right\}. \quad (72)$$

At the vertical boundary between regions II and III there exist four additional conditions which are comparable to the four already given. Expressing the displacement of the lower layer of region II at this point, we have the condition

$$\left.\begin{matrix} y=-c \\ y_0^{II}=-a \end{matrix}\right\}. \quad (73)$$

The vanishing of the thickness of the lower layer gives the condition that

$$\left.\begin{matrix} y=-c \\ \dfrac{dy_0^{II}}{dy}=0 \end{matrix}\right\}. \quad (74)$$

Continuity of displacements gives the relation that when

$$\left.\begin{matrix} y=-c \\ y_0^{III}=y_0^{II'} \end{matrix}\right\}. \quad (75)$$

Finally again continuity of depth gives the condition

$$\left.\begin{matrix} y=-c \\ \dfrac{dy_0^{III}}{dy}=\dfrac{dy_0^{II'}}{dy} \end{matrix}\right\}. \quad (76)$$

Imposing these eight boundary conditions in the order given upon the fundamental equations (12), (16), (63), and (64), there result the eight equations written below:

$$-a\alpha=\frac{1}{2}[K_1-K_2+Q_1-Q_2] \quad (77)$$

$$-\alpha=\frac{1}{2}[K_1\kappa_1-K_2\kappa_2-Q_1\kappa_1+Q_2\kappa_2] \quad (78)$$

$$Q^I=\frac{1}{2}[K_1+K_2+Q_1+Q_2] \quad (79)$$

$$-\frac{1}{\lambda}Q^I=\frac{1}{2}[K_1\kappa_1+K_2\kappa_2-Q_1\kappa_1-Q_2\kappa_2] \quad (80)$$

$$c-a=\frac{1}{2}[K_1e^{-\kappa_1 c}+K_2e^{-\kappa_2 c}+Q_1e^{\kappa_1 c}+Q_2e^{\kappa_2 c}] \quad (81)$$

$$-1=\frac{1}{2}[K_1\kappa_1e^{-\kappa_1 c}+K_2\kappa_2e^{-\kappa_2 c}-Q_1\kappa_1e^{\kappa_1 c}-Q_2\kappa_2e^{\kappa_2 c}] \quad (82)$$

$$\alpha Q^{III}e^{-\frac{c}{\lambda}}=\frac{1}{2}[K_1e^{-\kappa_1 c}-K_2e^{-\kappa_2 c}+Q_1e^{\kappa_1 c}-Q_2e^{\kappa_2 c}] \quad (83)$$

$$\alpha Q^{III}\frac{1}{\lambda}e^{-\frac{c}{\lambda}}=\frac{1}{2}[K_1\kappa_1e^{-\kappa_1 c}-K_2\kappa_2e^{-\kappa_2 c}-Q_1\kappa_1e^{\kappa_1 c}+Q_2\kappa_2e^{\kappa_2 c}] \quad (84)$$

It will be noted that all the constants enter these equations linearly except c, which is contained both linearly and exponentially. It is therefore possible to eliminate the six constants of integration and a algebraically, the result being a single exponential equation in c which can be solved by trial for any particular numerical example. When this has been accomplished, the remaining constants may be determined without difficulty. The actual process of carrying out the elimination becomes rather involved, however, and it would not be practical to reproduce the necessary steps in this discussion.

From the relation expressed by (62) it is seen that the solution of the entire problem depends in no way upon the absolute values of the densities but only upon their ratio $\frac{\rho'}{\rho}$. Taking a figure of 0.960,788 for this ratio, α, κ^1, and κ^2 have the following values:

$$\alpha=0.980,198$$

$$\kappa_1=\frac{0.710,634}{\lambda}$$

$$\kappa_2=\frac{7.106,335}{\lambda}$$

This particular choice of $\frac{\rho'}{\rho}$ makes κ_2 exactly ten times larger than κ_1 which simplifies the calculation slightly.

Corresponding to these conditions the eight constants to be determined assume the numerical values given below in terms of λ. It will be found that these figures satisfy the last eight equations sufficiently closely for practical purposes.

$$c=+0.336,10\lambda$$
$$a=+0.159,07\lambda$$
$$Q^{I}=+0.009,08\lambda$$
$$Q^{III}=+0.010,78\lambda$$
$$K_1=-0.769,48\lambda$$
$$K_2=+0.150,86\lambda$$
$$Q_1=+0.622,61\lambda$$
$$Q_2=+0.014,20\lambda$$

Inserting these figures in the expression for the depths discussed previously, and assuming a value of D_0 equal to the height of the homogeneous atmosphere which is taken to be eight kilometers, the shape of the free surface and of the internal boundary may be plotted. In this way the diagram reproduced in figure 3 is obtained. In middle latitudes the value of λ is approximately 2,800 km., which gives a horizontal scale for the diagram.

Likewise the velocities may now be obtained. These are also plotted in figure 3, the unit of velocity being $f\lambda$ which in middle latitudes has the approximate value of 280 meters per second. The directions are taken as corresponding to the Northern Hemisphere.

The general features of the final state may now be described as follows: Beginning with region I, there is here a shift of the fluid to the right amounting to 0.00908λ at the point $y=0$, and decreasing with increasing positive values of y. This leads to a slope downward to the right of the free surface and the generation of mild easterly winds as shown in the velocity diagram. In region III there is also a shift of the fluid to the right amounting to 0.00771λ at $y=-0.3361\lambda$ and decreasing to zero for large negative values of y. This causes a piling up of the fluid in this region so that the free surface again slopes downward to the right and provides the necessary Coriolian pressure gradient for the mild easterly winds indicated on the velocity chart. In region II the original discontinuity M is located at $y=-0.15907\lambda$. In the lower layer there exist easterly winds which at the boundary $y=0$ are equal in intensity to those in region I at this point, since continuity of displacement exists at the boundary. Farther to the right these increase rapidly and reach a maximum at the point $y=-0.3361\lambda$. The Coriolian pressure gradient, as already mentioned, is here provided by the inclination of the internal boundary and of the free surface.

In the upper layer the lateral displacement of the vertical columns may be thought of as the sum of two effects.

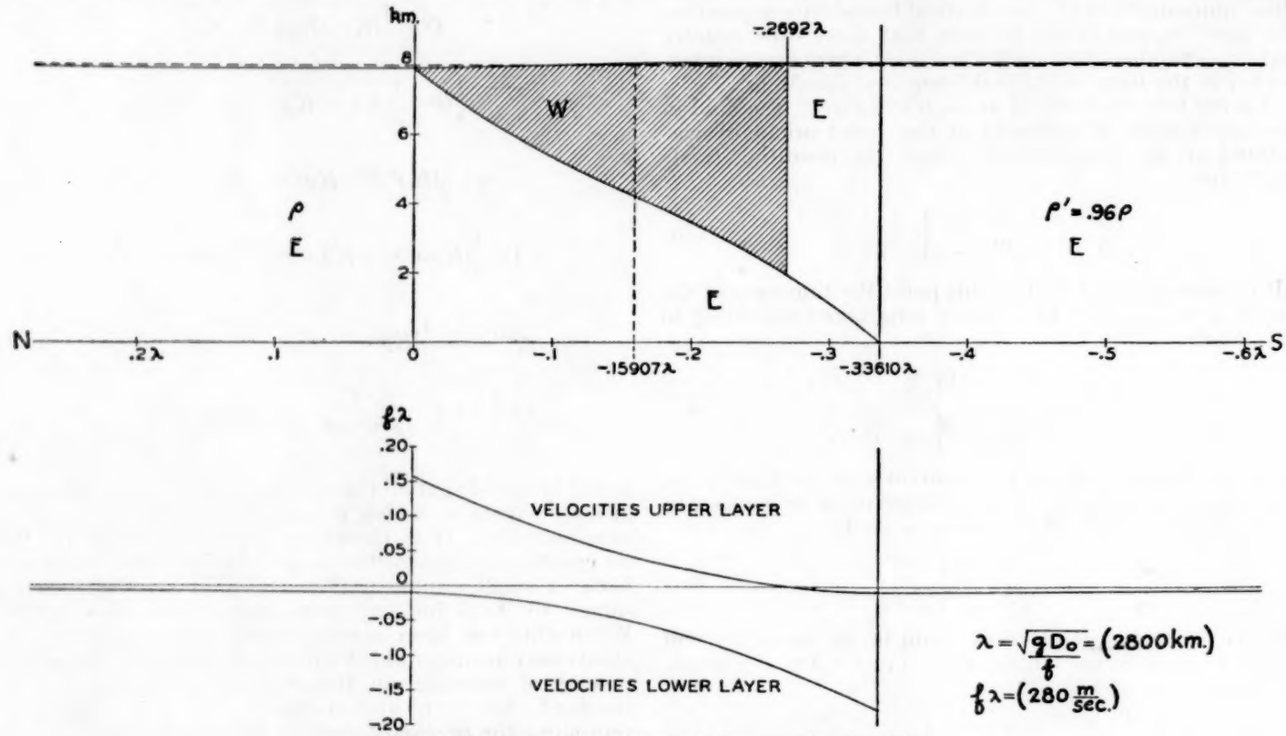

FIGURE 3.—Readjustment of two air masses under conservation of vorticity.

In the first place, since there is a shift of the fluid in region III to the right, and since there must be continuity of displacement at the vertical boundary, the liquid in the upper layer in the vicinity of the boundary must take part in this motion to the right. Secondly, the vertical shrinking of the fluid columns from the original height D_0 to that shown on figure 3 must lead to a displacement to the left in order to preserve continuity of volume. Because these two effects oppose one another, there must exist a vertical in the upper layer of region II at which the displacement, the velocity, pressure gradient and slope of the free surface are all zero. By setting $y_0^{II'}=y$ in equation (63) this vertical is found to be at $y=-0.2692\lambda$. It is also apparent that the elevation of the free surface must reach a maximum at this point. This turns out to be 8.064 km., or 64 meters

above the initial depth of the fluid layer. The velocities for the upper layer are as shown, being mild easterly to the right of this vertical and increasing westerly to the left. The free surface has an increasing slope downward to the left, the depth reaching a minimum at $y=0$ where the value is 7.927 km. or 73 meters below the initial depth.

Having obtained a description of the equilibrium state, it becomes a matter of interest to examine the energy changes that must occur during the transition. Initially the system possesses no kinetic energy, but has a certain amount of potential energy of mass distribution. In the final state a certain kinetic energy of transverse circulation exists, while the potential energy is less than originally. It is now proposed to make a quantitative calculation of these energy changes.

The change of potential energy between the two states in region I may be expressed in the form of the following integral; energy rendered available being reckoned as positive:

$$\int_0^\infty \left(\frac{D_0}{2}-\frac{D^{\mathrm{I}}}{2}\right)\rho g D^{\mathrm{I}} dy. \tag{85}$$

Upon substitution for D^{I} from (14) and integration between the limits indicated it is found that this quantity assumes the value of $0.004{,}519\ \rho g D_0^2\lambda$. Taking cognizance of the fact that one dimension of length is suppressed, it will be seen that this quantity has the dimensions of energy.

The corresponding integral for region III gives the result that the change in potential energy is $-0.003{,}866\ \rho' g D_0^2\lambda$ or $-0.003{,}714\rho g D_0^2\lambda$.

In region II it is convenient to calculate the change in potential energy for each layer independently. In the lower layer an integral of the form of (85) may be applied directly, although the integration is more laborious than in regions I and III. The result is that the change in potential energy is equal to $0.030{,}442\rho g D_0^2\lambda$. For the upper layer the integral has the form

$$\int_{-0.3361\lambda}^0 \left[\frac{D_0}{2}-\left(D^{\mathrm{II}}+\frac{D^{\mathrm{II}'}}{2}\right)\right]\rho' g D^{\mathrm{II}'} dy. \tag{86}$$

The evaluation of this quantity gives as a result $-0.031{,}174\rho' g D_0^2\lambda$ or $-0.029{,}952\rho g D_0^2\lambda$.

Summing for the three regions the net change in potential energy turns out to be $+0.001{,}295\rho g D_0^2\lambda$.

The kinetic energy of the transverse circulation for region I may be expressed in the form of the integral,

$$\int_0^\infty \frac{u^{\mathrm{I}2}\rho D^{\mathrm{I}} dy}{2}, \tag{87}$$

which turns out to have a value of $0.000{,}020\ \rho f^2 D_0\lambda^3$. The unit of energy appearing here will be seen to be equivalent to that occurring in the calculation of potential energy if the value of $\frac{gD_0}{f^2}$ be substituted for λ^2. Corresponding integrals may be set up for the remaining regions, giving the result that the kinetic energy is $0.000{,}150\rho f^2 D_0\lambda^3$ and $0.000{,}257\rho f^2 D_0\lambda^3$ for the upper and lower layers of region II, respectively, and $0.000{,}029\ \rho f^2 D_0\lambda^3$ for region III. Summing for the three regions, the total kinetic energy of transverse circulation for the system becomes $0.000{,}456\rho f^2 D_0\lambda^3$.

Comparing this figure with that for the potential energy liberated during the readjustment, it is seen that the latter is about three times as large as the former, and the question arises as to the physical meaning of the large difference between these quantities. It will be recalled that in the original statement of the problem the assumption was made that the transition from the initial to the final state proceeds infinitely slowly. Under these conditions it is permissible to neglect all accelerations in the y direction so that the system arrives at the equilibrium state without any finite velocities in the y direction.

Had this restriction not been made, but instead the readjustment allowed to take place at its natural rate, the solution obtained above would no longer describe completely the conditions when the system arrives at the equilibrium state. In addition to the transverse velocities in the x direction there would also exist finite velocities in the y direction. By virtue of these velocities the readjustment would proceed beyond the equilibrium state, then reverse its direction and the system would continue to oscillate about the equilibrium position. It appears that the fraction of the potential energy liberated which is not used to establish a transverse circulation represents energy of inertia oscillations whose character, however, cannot be in any way determined from this investigation.

It remains to be pointed out, however, that in general differences in density in the atmosphere are set up largely by gradual radiative processes, and that readjustment of actual atmospheric systems takes place simultaneously with the slow establishment of density differences. For this reason readjustment processes must automatically take place on a nearly quasistatic basis, passing through an infinite number of equilibrium stages, and arriving at the final state without appreciable energy of oscillation. Under these conditions the amount of heat energy required to bring about the change in density is less than would be required if the heating and expansion took place prior to the readjustment of mass distribution.

As a variation of the above problem it would be of interest to determine the changes that would be produced if a third mass of relatively lighter fluid overlies the two overturning air masses. Strictly speaking, since there would be upon readjustment a deformation of the internal boundary between the two layers thus formed, lateral convergence and divergence accompanied by the generation of weak transverse circulation and also a deformation of the free surface should be expected in the upper layer. If, however, the upper layer is relatively deep, these effects would be sufficiently small to be neglected, the upper layer being considered at rest with a level surface in the final state as well as initially.

An examination of the conditions imposed by the addition of such a layer shows that almost the same fundamental equations as were previously derived will serve to specify the solution of a problem of this type, provided that for each set of densities chosen, the initial depths of the two air masses comprising the lower layer bear a given fixed ratio to each other. We may thus represent the initial (dashed lines) and final states schematically as in figure 4.

In region I the pressure at the surface may be expressed as follows:

$$p_g=\rho D^{\mathrm{I}}+\rho''(D_0'-D^{\mathrm{I}})+p_c \tag{88}$$

where p_g is the pressure at the level D_0'. When this is differentiated with respect to y,

$$\frac{\partial p_g}{\partial y}=(\rho-\rho'')\frac{\partial D^{\mathrm{I}}}{\partial y}. \tag{89}$$

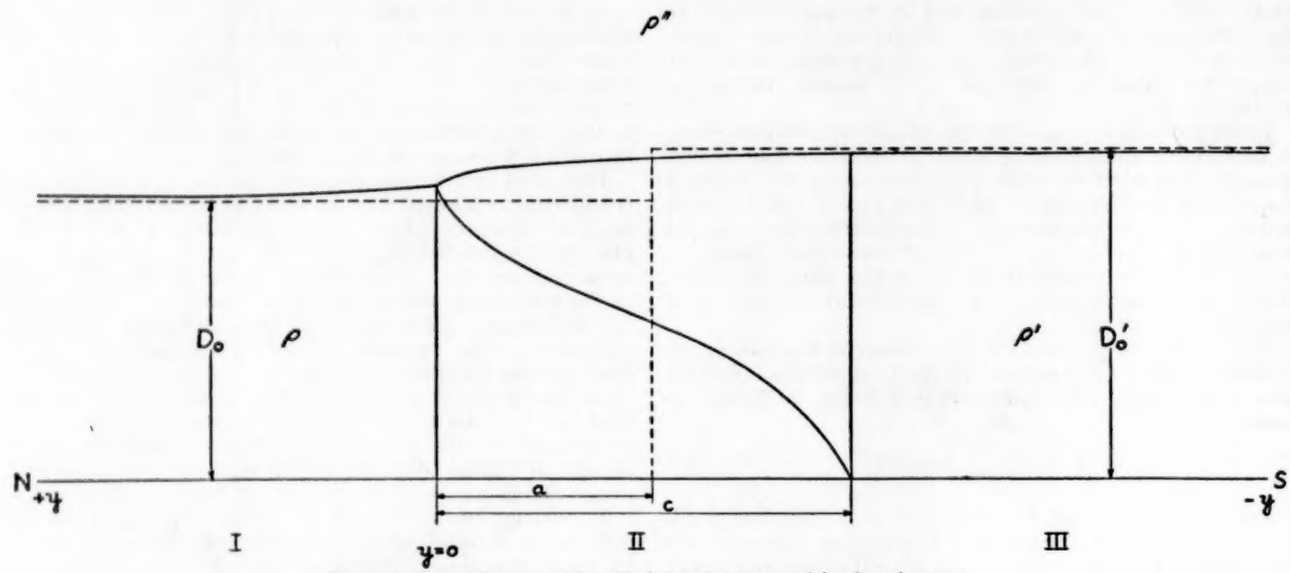

FIGURE 4.—Schematic representation of final state of system containing three air masses.

Incorporating this expression for the pressure gradient in equation (6) and proceeding as in the previous problem, the fundamental equation for this region is found to be,

$$y_0^{\mathrm{I}}=y+Q^{\mathrm{I}}e^{-\frac{y}{\lambda^{\mathrm{I}}}} \tag{90}$$

in which λ^{I} is now defined as

$$\lambda^{\mathrm{I}}=\frac{\sqrt{gD_0\frac{\rho-\rho''}{\rho}}}{f}. \tag{91}$$

Exactly similar considerations lead to the following fundamental equation for region III,

$$y_0^{\mathrm{III}}=y+Q^{\mathrm{III}}e^{\frac{y}{\lambda^{\mathrm{III}}}} \tag{92}$$

where λ^{III} is given by

$$\lambda^{\mathrm{III}}=\frac{\sqrt{gD_0'\frac{\rho'-\rho''}{\rho'}}}{f} \tag{93}$$

In region II the pressure gradients may be obtained from the following expressions for p_g' and p_g:

$$p_g'=g\rho'(D^{\mathrm{II}}+D^{\mathrm{III}'}-Z)+g\rho''(D_0'-D^{\mathrm{II}}-D^{\mathrm{III}'})+p_c, \tag{94}$$

$$p_g=g\rho D^{\mathrm{II}}+g\rho'D^{\mathrm{III}'}+g\rho''(D_0'-D^{\mathrm{II}}-D^{\mathrm{III}'})+p_c. \tag{95}$$

Differentiating these

$$\frac{\partial p_g'}{\partial y}=g\rho'\left(\frac{\partial D^{\mathrm{II}}}{\partial y}+\frac{\partial D^{\mathrm{III}'}}{\partial y}\right)-g\rho''\left(\frac{\partial D^{\mathrm{II}}}{\partial y}+\frac{\partial D^{\mathrm{III}'}}{\partial y}\right); \tag{96}$$

$$\frac{\partial p_g}{\partial y}=g\rho\frac{\partial D^{\mathrm{II}}}{\partial y}+g\rho'\frac{\partial D^{\mathrm{III}'}}{\partial y}-g\rho''\frac{\partial D^{\mathrm{III}'}}{\partial y}. \tag{97}$$

Carrying out similar operations as previously, an equation comparable to (40) is obtained:

$$0=f^2[y_0^{\mathrm{II}}+\alpha y_0^{\mathrm{II}'}-(1+\alpha)y]-gD_0\left[\frac{\rho-\rho''}{\rho}+\frac{\rho'-\rho''}{\rho'}\right]\frac{d^2}{dy^2}\left[y_0^{\mathrm{II}}+\frac{D_0'\left(\frac{\rho'-\rho''}{\rho}+\frac{\rho'-\rho''}{\rho'}\alpha\right)}{D_0\left(\frac{\rho-\rho''}{\rho}+\frac{\rho'-\rho''}{\rho'}\alpha\right)}y_0^{\mathrm{II}'}\right] \tag{98}$$

Again defining α by equating the coefficients of $y_0^{\mathrm{II}'}$ and solving, the following equation results:

$$\alpha=\frac{1}{2}\left[\frac{D_0'}{D_0}-\frac{\rho'(\rho-\rho'')}{\rho(\rho'-\rho'')}\pm\sqrt{\left\{\frac{D_0'}{D_0}-\frac{\rho'(\rho-\rho'')}{\rho(\rho'-\rho'')}\right\}^2+\frac{4\rho'D_0'}{\rho D_0}}\right] \tag{99}$$

If now the fundamental equations for region II are to have the same form as (63) and (64), it is necessary that the roots of this equation differ only as to sign, as was the case previously. This imposes the condition that

$$\frac{D_0'}{D_0}-\frac{\rho'(\rho-\rho'')}{\rho(\rho'-\rho'')}=0. \tag{100}$$

Retaining the same ratio of densities in the lower layer as was used in the first problem and assuming that $\rho''=0.80\rho$, the value of the ratio $\frac{D_0'}{D_0}$ turns out to be 1.195,098.

The quantity α now becomes equal to $\sqrt{\frac{\rho'D_0'}{\rho D_0}}$, while the constants κ_1, κ_2, and λ are defined as follows:

$$\kappa_1=\frac{1}{\lambda\sqrt{\frac{\rho-\rho''}{\rho}+\frac{\rho'-\rho''}{\rho'}\alpha}} \tag{101}$$

$$\kappa_2=\frac{1}{\lambda\sqrt{\frac{\rho-\rho''}{\rho}-\frac{\rho'-\rho''}{\rho'}\alpha}} \tag{102}$$

$$\lambda=\frac{\sqrt{gD_0}}{f} \tag{103}$$

The condition (100) also causes λ^{I} to be equal to λ^{III}.

The determination of the constants to be fixed by boundary conditions can be done in almost exactly the same manner as before, leading to the numerical values given below:

$$c=+0.338,15\lambda$$
$$a=+0.180,20\lambda$$
$$Q'=-0.007,12\lambda$$
$$Q'''=-0.027,72\lambda$$
$$K_1=-0.425,19\lambda$$
$$K_2=+0.171,17\lambda$$
$$Q_1=+0.224,97\lambda$$
$$Q_2=+0.014,81\lambda$$

The expressions for the depths and for the velocities are formed as previously, and if the results are plotted on the same scale as before the diagram shown in figure 5 is obtained. It is seen that now a weak west wind prevails in regions I and III and also in the left portion of the lower layer of region II. The upper layer now has a continuous distribution of westerly winds, while the right hand portion of the lower layer in region II has easterly winds with velocities as shown. The initial state is shown by the dashed lines.

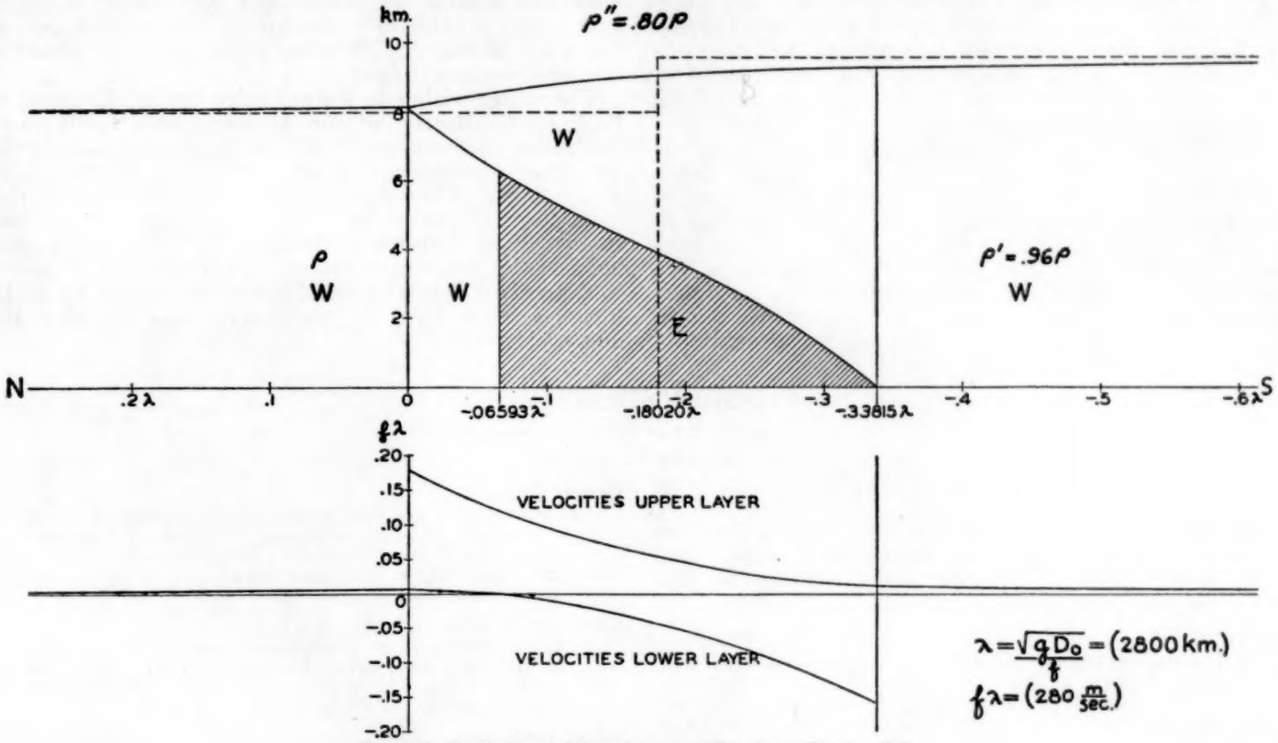

FIGURE 5.—Readjustment of three air masses under conservation of vorticity.

In concluding, it might be remarked that the above analyses depend essentially upon the fact that in an incompressible fluid of uniform density, that is, in a homogeneous and incompressible fluid, there can be no variation of gradient wind with elevation. This is also true for a homogeneous and compressible fluid such as an adiabatic atmosphere. It should therefore be possible, at least in theory, to carry out a similar calculation for a system composed of two air masses each having a constant potential temperature.

SUMMARY

1. If, on a rotating earth, a layer of incompressible fluid of uniform depth and infinite horizontal extent composed of two motionless fluid masses of differing density and separated initially by a plane vertical partition, is allowed to readjust itself slowly upon removal of the partition, the system will come to a state of equilibrium in which the two masses are separated by an inclined boundary sloping downward toward the lighter fluid mass, and in which the free surface is deformed in such a manner that the maximum depth occurs at a point above the internal boundary and the minimum depth at the point where the thickness of the lighter fluid becomes zero. In obtaining this result and those that follow, all frictional effects as well as mixing at the mutual boundary of the fluids, are assumed to be absent. The Coriolis parameter is not assumed to vary within the dimensions of the system. For an initial depth of 8 km. and a ratio of densities equal to 0.96 the shape of the free surface and internal boundary is given by figure 3.

2. Due to the action of pressure gradients and Coriolis forces during the readjustment of the above system, horizontal velocities parallel to the original discontinuity will be set up. The distribution of these velocities will be such that if in the Northern Hemisphere the discontinuity is imagined, for the purpose of reference, as extending from east to west with the lighter fluid to the south, easterly velocities will appear in the denser fluid, decreasing to zero at great distances to the north and increasing southward to a maximum at the point where the thickness of the heavier fluid becomes zero.

In the lighter fluid the velocity will be zero at great distances to the south and also along the vertical at which the elevation of the free surface is a maximum. To the south of this vertical the velocities will be mild easterly,

having a maximum above the point where the internal boundary intersects the lower surface of the layer. To the north of this vertical, westerly velocities increasing northward will prevail, reaching a maximum at the point where the thickness of the lighter fluid becomes zero. Within each mass of fluid there will be no variation of velocity with elevation. A graph of the velocities for a density ratio of 0.96 and an initial depth of 8 km. is given in figure 3. The unit of velocity used is a function of geographical latitude and amounts to about 280 meters per second in middle latitudes.

3. In the above system there will be a decrease of potential energy of mass distribution during the readjustment. Also, there will exist in the final state a certain amount of kinetic energy represented by the velocity distribution already described. Computation on the example already cited shows that the amount of potential energy set free is nearly three times as great as the kinetic energy represented by the circulaiton set up. The difference between these two quantities is accounted for by the fact that the readjustment was assumed to take place slowly on a quasistatic basis, implying the existence of an external retarding agency which absorbs a portion of the potential energy rendered available.

If the process is considered as taking place at its natural rate, the system will then arrive at the equilibrium point with a certain amount of kinetic energy of oscillation. If this additional kinetic energy is included, the sum of potential and kinetic energy for the system remains constant at all stages of the process. The character of the oscillations performed by the system cannot be determined from this analysis. However, it is probable that in the actual atmosphere density differences are generally set up gradually, so that readjustment processes automatically proceed in an almost quasistatic manner, and energy of oscillation does not appear to a significant extent.

4. A problem comparable to the above but involving the presence of a third mass of fluid overlying the system can be treated by almost exactly the same mathematical set-up save for numerical values as was used in the first analysis, provided that the depth of the third mass is relatively large in comparison with the other two, and that the initial depths of the first two masses bear the following relation to the densities chosen:

$$\frac{D_0'}{D_0}=\frac{\rho'(\rho-\rho'')}{\rho(\rho'-\rho'')},$$

where D_0 and D_0' are the depths of the heavier and lighter fluids respectively and ρ and ρ' their densities, while ρ'' is the density of the third mass.

Taking the same value for the ratio of densities in the lower two masses and assuming a value of ρ'' equal to 0.80 ρ, and a value of 8 km. for D_0, the result shown in figure 5 is obtained. The diagram is to be interpreted in the same manner as figure 3.

The writer wishes to acknowledge his indebtedness to Prof. C. G. Rossby of the Massachusetts Institute of Technology for suggesting this investigation, and for the continual assistance and encouragement which he so gladly gave. The underlying principles involved in this work form a part of the material covered by Professor Rossby in his lectures at the Institute which the author has had the pleasure to attend. Also, the author desires to express his appreciation of the help rendered by R. D. Fletcher in reading the manuscript and checking the numerical work.

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SOLAR OBSERVATIONS

[Meteorological Research Division, EDGAR W. WOOLARD in charge]

SOLAR RADIATION OBSERVATIONS, MAY 1939

By IRVING F. HAND

Measurements of solar radiant energy received at the surface of the earth are made at eight stations maintained by the Weather Bureau, and at nine cooperating stations maintained by other institutions. The intensity of the total radiation from sun and sky on a horizontal surface is continuously recorded (from sunrise to sunset) at all these stations by self-registering instruments; pyrheliometric measurements of the intensity of direct solar radiation at normal incidence are made at frequent intervals on clear days at three Weather Bureau stations (Washington, D. C., Madison, Wis., Lincoln, Nebr.) and at the Blue Hill Observatory of Harvard University. Occasional observations of sky polarization are taken at the Weather Bureau stations at Washington and Madison.

The geographic coordinates of the stations, and descriptions of the instrumental equipment, station exposures, and methods of observation, together with summaries of the data, obtained up to the end of 1936, will be found in the MONTHLY WEATHER REVIEW, December 1937, pages 415 to 441; further descriptions of instruments and methods are given in Weather Bureau Circular Q.

Table 1 contains the measurements of the intensity of direct solar radiation at normal incidence, with means and their departures from normal (means based on less than 3 values are in parentheses). At Madison and Lincoln the observations are made with the Marvin pyrheliometer; at Washington and Blue Hill they are obtained with a recording thermopile, checked by observations with a Marvin pyrheliometer at Washington and with a Smithsonian silver disk pyrheliometer at Blue Hill. The table also gives vapor pressures at 8 a. m. (75th meridian time) and at noon (local mean solar time).

During May normal incidence intensities averaged below normal at Washington, Madison, and Blue Hill and slightly above normal at Lincoln.

Total solar and sky radiation averaged above the May normals at all stations with the exception of Miami, New Orleans, Riverside, Friday Harbor, Ithaca, and Newport. It is interesting to note that all the inland stations with the exception of Ithaca had large plus departures, while every coastal station showed a deficiency.

TABLE 1.—*Solar radiation intensities during May 1939*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance										
	8a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 4	4.57				1.15	1.44	0.96				4.75
May 5	7.04			0.62	0.80						4.95
May 6	8.18				.78						8.18
May 10	8.81					1.38					7.29
May 12	4.95					1.40					4.37
May 15	6.27			.93	1.16	1.46					3.00
May 23	15.65				.68						11.10
May 24	11.38	0.34	0.42	.69	1.04	1.41					8.18
May 31	14.60			.97	1.07						12.24
Means		(.34)	(.42)	.80	.95	1.42	(.96)				
Departures		−.29	−.30	−.04	−.06	+.14	+.02				

TABLE 1.—*Solar radiation intensities during May 1939*—Continued

MADISON, WIS.

Date	Sun's zenith distance										
	8a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 1	4.57			0.89	1.00	1.48					4.95
May 2	4.57		0.84	1.07	1.25	1.48					4.78
May 5	8.48			.72	0.87	1.31					9.47
May 6	7.04			.77	1.06						6.76
May 9	6.76			.81	1.12	1.39					4.57
May 10	5.79					1.09					4.37
May 11	4.75			1.00	1.24						4.57
May 12	3.99		.64	.80							5.36
May 13	4.57		.61	.78	1.12	1.32					4.57
May 16	9.83					1.38					8.18
May 19	11.38					1.30					11.81
May 24	10.72	0.47	.57	.79	1.00	1.26					11.38
May 25	11.38	.36	.43	.64	.83						14.10
May 31	15.65			.96	1.15						16.20
Means		.42	.62	.84	1.06	1.33					
Departures		−.30	−.20	−.15	−.06	−.05					

LINCOLN, NEBR.

May 1	6.27	0.68	0.77	0.90	1.17		1.11	0.88	0.71	0.58	7.04
May 4	9.14						1.01	.79	.65	.51	11.81
May 5	10.21		.69	.84	1.07						9.47
May 6	8.18			.69							11.81
May 9	4.95	.90	1.03	1.17	1.34	1.52	1.25	1.04	.87		6.27
May 13	4.95				1.22						6.02
May 15	4.95		.98	1.13	1.31		1.22	1.04	.89		5.56
May 16	5.79		.84	.97	1.16	1.42					8.81
May 19	10.21		.85	.95	1.16						13.13
May 23	14.60						1.03	.80	.64		17.37
May 25	16.79				1.06						16.20
May 29	10.59		.93	1.08	1.25	1.47		1.02	.85		9.83
May 31	15.65				1.13	1.46					9.47
Means		(.79)	.87	.97	1.19	1.47	1.12	.93	.77	(.54)	
Departures		+.12	+.08	+.05	+.08	+.09	+.01	+.02	−.02	−.13	

BLUE HILL, MASS.

May 1	4.2				1.13						4.0
May 5	6.5					1.18					6.8
May 6	6.1					1.05	0.80	0.50			7.6
May 7	9.6				.80				0.46	0.35	6.8
May 10	8.6					1.42		.87	.73	.61	6.3
May 12	4.8				1.23	1.40	1.18	1.03	.85	.74	3.8
May 14	4.6				1.10	1.42	1.15	.90	.80	.68	4.8
May 15	3.6					1.38	1.22	1.08	.95	.86	4.0
May 16	5.0					1.46					4.6
May 18	6.1						1.18	.95			2.0
May 20	7.9					1.11	.80				9.6
May 24	7.4					1.41					7.1
May 26	7.6						.99	.85	.71		5.8
May 30	10.7					1.35			.71		9.9
May 31	12.3					1.24			.50		9.6
Means					1.06	1.31	1.05	.88	.71	.65	
Departures					−.07	−.06	−.04	−.03	−.06	−.05	

*Extrapolated.

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	San Juan	Friday Harbor	Ithaca	Newport
	Gram-calories per square centimeter																
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 30	525	637	572	573	446	691	383	569	583	451	462	545	442	672	504	474	457
May 7	*516	542	578	532	439	598	444	615	499	452	475	466	495	674	668	370	495
May 14	670	604	610	535	588	659	517	579	531	496	429	471	704	580	514	478	686
May 21	617	587	574	558	400	683	411	641	700	495	362	644	401	629	493	308	429
May 28	492	532	680	559	557	698	565	646	501	491	338	539	661	615	556	275	699
	Departures of daily totals from normals																
Apr. 30	+55	+190	+97	+177	+48	+60	−16	+51	+21	−59	+59	−6	−51	+55	−50	+92	−46
May 7	+61	+91	+123	+123	+44	−48	−6	+24	−61	−62	+70	−83	+4	+110	+108	−33	−25
May 14	+199	+124	+90	+106	+166	−9	+44	−27	+9	+2	+20	−39	+174	+77	−34	+25	+160
May 21	+112	+92	+19	+90	−45	+6	−38	−5	+195	−5	−52	+90	−127	+67	−68	−179	−115
May 28	−27	+34	+152	+85	+84	+10	+128	+49	−29	+23	−145	−12	+79	+33	0	−194	−33
	Accumulated departures since Jan. 1																
	+5,915	+4,669	+3,899	+6,888	+1,575	−581	−595	+119	+2345	+896	+5,019	−1,841	−840	+7,189	+1,907	−6,713	−1,547

*5-day mean.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, U. S. Navy (Ret.) Superintendent, U. S. Naval Observatory. Data from measurements at the U. S. Naval Observatory from plates obtained at the observatories indicated. Difference in longitude is measured from the central meridian, positive toward the west. Latitude is positive toward the north. Areas are corrected for foreshortening and expressed in millionths of Sun's visible hemisphere. For each day, below longitude, latitude, area of spot or group, and spot count, are given respectively the assumed longitude of the center of the disk, assumed latitude of the center of the disk, total area of spots and groups, and total spot count]

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
May 1	11 12	6424	−88	78	+12	88	194	2	VG	U. S. Naval.
		6423	−80	86	−11	80	24	1		
		6422	−53	113	+22	59	24	2		
		6418	−49	117	+12	51	727	10		
		6414	−22	144	−23	29	97	6		
		6417	−19	147	−11	21	48	1		
		6413	−12	154	+22	27	24	3		
		6414	−11	155	−21	20	61	1		
		6417	−11	155	−10	13	85	1		
		6413	−5	161	+21	25	121	7		
		6415	−5	161	+12	16	145	16		
		6421	+3	169	−16	13	48	4		
		6410	+33	199	−11	34	145	2		
		6410	+39	205	−10	39	20	6		
		6412	+59	225	−15	60	174	6		
		6420	+59	225	+18	62	61	4		
		6407	+68	234	+30	73	824	16		
		6406	+72	238	−17	72	485	1		
		6408	+77	243	+6	78	97	1		
		6405	+80	246	+25	82	97	1		
				(166)	(−4)		3,501	91		
May 2	8 59	6424	−76	78	+11	77	582	12	VG	Mt. Wilson.
		6423	−69	85	−9	69	73	3		
		6422	−38	116	+22	46	291	16		
		6418	−37	117	+11	40	727	45		
		6414	−12	142	−23	23	145	3		
		6417	−7	147	−11	10	12	3		
		6414	−3	151	−21	18	145	14		
		6417	+1	155	−11	7	97	6		
		6415	+7	161	+11	16	36	6		
		6413	+8	162	+19	24	121	15		
		6421	+16	170	−18	22	36	28		
		6410	+37	191	−17	39	6	8		
		6410	+45	199	−11	45	97	4		
		6412	+68	222	−15	68	145	18		
		6420	+70	224	+16	72	97	11		
		6407	+82	236	+30	85	242	8		
		6406	+85	239	−17	85	194	2		
				(154)	(−4)		3,046	202		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
May 3	8 58	6424	−62	79	+11	64	582	18	VG	Mt. Wilson.
		6423	−54	87	−8	54	145	12		
		6422	−24	117	+22	34	339	55		
		6418	−23	118	+11	28	727	50		
		6414	+1	142	−23	20	73	18		
		6414	+10	151	−21	20	36	19		
		6417	+14	155	−11	16	73	10		
		6415	+20	161	+12	25	6	2		
		6413	+20	161	+19	30	85	7		
		6410	+59	200	−11	59	97	6		
		6420	+82	223	+15	83	36	3		
		6412	+83	224	−14	83	194	4		
				(141)	(−4)		2,393	204		
May 4	10 59	6426	−76	51	+8	77	48	1	G	U. S. Naval.
		6424	−47	80	+11	49	436	10		
		6423	−41	86	−9	41	61	4		
		6418	−13	114	+14	21	436	21		
		6422	−12	115	+22	28	485	36		
		6418	−9	118	+11	17	339	9		
		6414	+15	142	−23	24	36	5		
		6414	+28	155	−20	33	12	1		
		6417	+29	156	−11	30	61	1		
		6413	+38	165	+19	44	109	7		
		6425	+47	174	−7	47	24	3		
		6410	+74	201	−11	74	145	1		
				(127)	(−4)		2,192	99		
May 5	11 31	6426	−63	50	+9	65	48	2	VG	Do.
		6424	−35	78	+10	37	97	16		
		6424	−31	82	+11	34	388	1		
		6423	−26	87	−9	26	121	12		
		6418	+2	115	+14	17	533	66		
		6422	+2	115	+23	26	533	42		
		6418	+6	119	+11	16	436	12		
		6417	+42	155	−10	42	48	1		
		6413	+50	163	+19	54	73	6		
		6425	+61	174	−7	67	6	1		
		6410	+80	193	−15	80	48	4		
		6410	+83	196	−11	83	48	1		
				(113)	(−4)		2,379	164		
May 6	10 58	6426	−50	50	+9	51	24	2	VG	Do.
		6424	−22	78	+10	26	97	16		
		6424	−18	82	+12	23	291	5		
		6423	−13	87	−8	14	71	13		
		6422	+15	115	+23	30	533	38		
		6418	+15	115	+14	22	533	70		
		6418	+20	120	+11	25	388	10		
		6417	+56	156	−9	50	61	1		
		6413	+63	163	+19	57	73	4		
				(100)	(−4)		2,071	159		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
May 7...	12 36	6431	−78	8	−3	78	170	1	F	U. S. Naval.
		6430	−74	12	+10	76	97	1		
		6429	−71	15	+14	74	109	1		
		6426	−36	50	+9	38	12	1		
		6428	−9	77	+10	16	24	5		
		6424	−3	83	+12	15	291	1		
		6428	+1	87	+9	12	36	6		
		6423	+3	89	−7	6	6	5		
		6422	+29	115	+23	39	436	18		
		6418	+29	115	+14	34	436	30		
		6418	+33	119	+11	36	339	1		
		6417	+69	155	−9	69	48	1		
				(86)	(−4)		2,004	71		
May 8...	11 14	6432	−80	354	−6	80	388	1	G	Do.
		6431	−64	10	−3	64	145	1		
		6429	−63	11	+15	67	109	2		
		6430	−60	14	+10	62	73	1		
		6424	+3	77	+10	13	36	5		
		6424	+9	83	+13	18	315	1		
		6428	+15	89	+9	19	24	3		
		6422	+42	116	+24	49	485	28		
		6418	+43	117	+14	46	485	50		
		6418	+46	120	+11	48	339	4		
		6417	+83	157	−9	83	36	1		
				(74)	(−3)		2,435	97		
May 9...	11 4	6432	−70	351	−9	70	24	5	VG	Do.
		6432	−69	352	−6	69	279	15		
		6433	−66	355	−22	67	36	10		
		6429	−51	10	+13	53	36	6		
		6431	−50	11	−3	50	182	2		
		6429	−47	14	+15	50	71	8		
		6430	−47	14	+9	49	71	7		
		6424	+21	82	+13	26	291	6		
		6424	+21	82	+10	24	97	10		
		6428	+30	91	+10	33	61	5		
		6422	+54	115	+25	60	436	20		
		6418	+54	115	+15	56	533	35		
		6418	+59	120	+12	61	388	3		
				(61)	(−3)		2,505	132		
May 10...	11 19	6432	−56	351	−7	56	339	12	G	Do.
		6433	−51	356	−21	53	145	7		
		6431	−38	9	−3	38	158	2		
		6429	−34	13	+13	37	145	15		
		6430	−32	15	+9	34	194	15		
		6434	+2	49	+27	29	61	6		
		6424	+35	82	+14	39	291	1		
		6424	+35	82	+10	36	194	10		
		6428	+43	90	+10	45	97	6		
		6422	+69	116	+24	73	339	6		
		6418	+70	117	+14	73	970	15		
				(47)	(−3)		2,933	95		
May 11...	12 7	6438	−80	314	−18	80	121	1	VG	Do.
		6432	−42	352	−7	42	194	26		
		6437	−42	352	+17	46	18	1		
		6436	−40	354	−15	42	24	4		
		6433	−37	357	−22	40	145	10		
		6431	−24	10	−3	24	109	4		
		6429	−20	14	+13	25	97	12		
		6430	−19	15	+9	22	194	16		
		6434	+15	49	+27	33	97	8		
		6424	+47	81	+10	49	121	18		
		6424	+48	82	+14	50	291	1		
		6428	+57	91	+10	59	97	9		
		6435	+67	101	+11	69	24	4		
		6418	+83	117	+14	84	436	6		
		6423	+86	120	+23	88	194	5		
				(34)	(−3)		2,162	125		
May 12...	11 27	6438	−68	313	−18	69	61	3	F	Do.
		6437	−29	352	+17	35	18	1		
		6432	−29	352	−7	29	121	9		
		6436	−26	355	−15	28	109	3		
		6433	−25	356	−22	31	158	13		
		6431	−10	11	−3	10	73	6		
		6429	−7	14	+13	18	61	3		
		6430	−7	14	+9	14	109	7		
		6439	−3	18	−2	3	71	6		
		6434	+27	48	+26	39	145	1		
		6424	+60	81	+11	62	24	4		
		6424	+61	82	+13	64	242	3		
		6428	+79	100	+10	80	97	3		
				(21)	(−3)		1,289	62		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
May 13..	10 38	6441	−84	284	+9	85	145	1	F	Mt. Wilson.
		6438	−54	314	−19	56	71	10		
		6432	−14	354	−8	15	121	30		
		6433	−11	357	−22	21	170	32		
		6436	−10	358	−16	17	97	11		
		6440	0	8	+9	12	97	7		
		6431	+4	12	−3	4	71	9		
		6430	+7	15	+8	14	97	8		
		6429	+9	17	+12	17	121	10		
		6439	+10	18	−3	10	145	12		
		6434	+39	47	+26	47	70	14		
		6424	+74	82	+10	76	24	4		
		6424	+75	83	+12	78	242	1		
				(8)	(−3)		1,471	149		
May 14..	12 15	6441	−70	284	+8	72	109	1	F	U. S. Naval.
		6438	−40	314	−19	43	48	1		
		6432	0	354	−8	6	121	10		
		6433	+1	355	−19	16	18	1		
		6433	+3	357	−22	19	145	22		
		6436	+3	357	−15	13	121	12		
		6440	+14	8	+10	19	194	10		
		6431	+18	12	−2	18	73	5		
		6429	+21	15	+13	26	97	11		
		6430	+21	15	+9	24	145	8		
		6439	+25	19	−1	25	121	9		
		6434	+56	50	+26	62	36	5		
		6442	+63	57	+18	68	48	1		
				(354)	(−3)		1,276	96		
May 15..	11 17	6441	−57	284	+8	59	121	1	VG	Do.
		6438	−26	315	−18	29	73	2		
		6443	−23	318	+17	30	24	3		
		6432	+13	354	−7	14	73	10		
		6436	+15	356	−19	22	6	1		
		6433	+16	357	−22	24	242	40		
		6436	+17	358	−15	20	121	11		
		6440	+27	8	+10	30	194	30		
		6431	+31	12	−2	31	36	2		
		6429	+33	14	+13	37	73	7		
		6430	+35	16	+9	37	48	4		
		6439	+40	21	−1	40	73	1		
		6434	+68	49	+27	74	73	10		
		6442	+79	60	+19	82	194	14		
				(341)	(−3)		1,351	136		
May 16..	11 21	6441	−43	285	+9	45	121	1	F	Do.
		6438	−11	317	−17	18	61	1		
		6443	−10	318	+17	20	24	1		
		6432	+27	355	−6	28	61	4		
		6433	+29	357	−22	35	339	25		
		6436	+30	358	−14	32	73	5		
		6440	+40	8	+10	42	242	15		
		6431	+45	13	−2	45	12	1		
		6429	+47	15	+13	49	36	4		
		6430	+48	16	+10	50	36	2		
		6439	+55	23	+1	55	36	1		
				(328)	(−3)		1,041	60		
May 17..	11 12	6445	−78	237	−16	78	218	1	VG	Do.
		6441	−30	285	+9	32	170	1		
		6438	+2	317	−19	17	73	8		
		6444	+35	350	+19	40	6	6		
		6432	+39	354	−6	40	12	4		
		6433	+42	357	−21	46	533	30		
		6436	+45	0	−15	47	36	5		
		6440	+54	9	+11	55	242	30		
		6431	+58	13	−2	58	24	2		
		6429	+59	14	+14	61	18	1		
		6430	+62	17	+9	63	145	22		
		6439	+68	23	+1	69	36	5		
				(315)	(−2)		1,513	115		
May 18..	11 8	6447	−78	224	+17	78	242	2	G	Do.
		6445	−64	238	−16	65	218	1		
		6441	−17	285	+9	19	109	2		
		6446	+4	306	+14	16	36	5		
		6438	+15	317	−17	21	73	7		
		6433	+56	358	−21	59	388	10		
		6440	+66	8	+12	68	145	15		
		6431	+70	12	−2	70	12	1		
		6440	+74	16	+9	76	145	8		
		6430	+75	17	+8	77	97	1		
				(302)	(−2)		1,465	52		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
May 19..	11 6	6447	−63	226	+17	66	242	2	F	U. S. Naval.
		6445	−50	239	−16	52	194	4		
		6448	−25	264	−13	28	73	5		
		6441	−3	286	+9	9	109	1		
		6446	+18	307	+14	23	12	1		
		6438	+29	318	−17	32	48	6		
		6433	+68	357	−21	69	339	8		
				(289)	(−2)		1,017	27		
May 20..	10 32	6447	−50	226	+16	52	242	5	G	Do.
		6445	−38	238	−16	41	170	7		
		6448	−12	264	−12	16	48	7		
		6441	+10	286	+9	15	97	1		
		6438	+42	318	−16	45	48	2		
		6449	+54	330	−8	55	6	1		
		6433	+83	359	−20	83	145	7		
				(276)	(−2)		756	30		
May 21..	11 54	6452	−69	193	+29	73	121	2	G	Do.
		6451	−40	222	−10	41	194	20		
		6447	−36	226	+16	39	170	2		
		6450	−26	236	+29	40	36	3		
		6445	−22	240	−17	27	291	9		
		6448	+2	264	−12	10	85	5		
		6441	+24	286	+9	26	73	1		
		6438	+56	318	−16	58	48	2		
		6449	+68	330	−9	68	194	4		
				(262)	(−2)		1,212	48		
May 22..	11 11	6456	−78	171	−19	79	97	2	F	Do.
		6452	−57	192	+29	63	97	5		
		6451	−25	224	−10	26	436	15		
		6447	−22	227	+16	28	145	2		
		6445	−10	239	−17	18	218	3		
		6453	+7	256	−6	8	24	1		
		6441	+37	286	+9	39	73	2		
		6449	+79	328	−8	79	97	2		
				(249)	(−2)		1,187	32		
May 23..	11 6	6457	−76	160	+19	78	145	1	VG	Do.
		6456	−66	170	−19	67	127	4		
		6452	−42	194	+28	50	73	1		
		6452	−42	194	+24	48	24	1		
		6451	−13	223	−10	16	485	40		
		6447	−10	226	+16	20	145	4		
		6445	−6	230	−20	20	6	1		
		6445	+2	238	−16	15	182	3		
		6453	+19	255	−5	24	6	2		
		6441	+49	285	+9	50	85	2		
				(236)	(−2)		1,278	59		
May 24..	10 53	6458	−79	143	−16	79	61	1	G	Do.
		6457	−62	160	+20	65	121	2		
		6556	−51	171	−18	54	194	10		
		6552	−30	192	+27	40	170	8		
		6451	+1	223	−10	8	582	25		
		6447	+2	224	+16	17	121	3		
		6445	+7	229	−20	20	36	2		
		6445	+16	238	−17	22	145	4		
		6441	+63	285	+8	64	73	1		
				(222)	(−2)		1,503	56		
May 25..	13 46	6458	−66	142	−17	68	48	2	F	Do.
		6457	−49	159	+19	52	121	2		
		6456	−30	169	−18	42	436	3		
		6452	−17	191	+26	31	194	15		
		6447	+15	223	+17	23	121	4		
		6451	+16	224	−10	19	388	20		
		6445	+31	239	−17	35	145	2		
		6441	+78	286	+9	79	6	1		
				(208)	(−2)		1,459	49		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
May 26..	11 35	6463	−74	122	−17	75	36	4	G	U. S. Naval.
		6458	−51	145	−17	53	24	2		
		6462	−41	155	−10	42	12	4		
		6457	−38	158	+20	42	121	4		
		6461	−32	164	−10	23	12	1		
		6456	−27	169	−18	31	436	15		
		6452	−3	193	+26	27	170	10		
		6460	+14	210	−9	16	12	2		
		6451	+27	223	−10	28	485	15		
		6447	+30	226	+15	34	61	3		
		6445	+43	239	−17	46	121	1		
		6459	+61	257	−9	62	85	2		
				(196)	(−1)		1,575	63		
May 27..	10 51	6466	−80	103	+11	80	145	3	G	Do.
		6465	−76	107	+7	76	533	2		
		6464	−61	122	+21	64	6	1		
		6463	−58	125	−17	60	73	5		
		6462	−27	156	−11	28	73	9		
		6457	−24	159	+19	31	121	2		
		6456	−14	169	−19	23	194	12		
		6452	+10	193	+26	29	73	9		
		6451	+41	224	−10	42	388	20		
		6447	+42	225	+15	45	24	4		
		6445	+57	240	−17	59	121	2		
		6459	+72	255	−9	72	85	2		
				(183)	(−1)		1,838	71		
May 28..	12 1	6469	−79	90	−7	79	242	4	G	Do.
		6468	−74	95	−17	75	48	1		
		6466	−67	102	+11	68	61	5		
		6465	−63	106	+7	64	485	4		
		6464	−50	119	+23	55	48	6		
		6463	−42	127	−16	45	12	6		
		6462	−13	156	−12	17	97	7		
		6457	−9	160	+19	22	109	3		
		6456	0	169	−19	18	121	19		
		6456	+5	174	−20	20	97	7		
		6467	+18	187	−10	20	6	4		
		6452	+21	190	+24	32	194	30		
		6451	+55	224	−10	56	388	6		
		6447	+58	227	+15	60	6	4		
		6445	+70	239	−16	70	97	1		
				(169)	(−1)		2,011	107		
May 29..	10 57	6471	−78	78	+13	79	242	1	VG	Do.
		6470	−76	80	−21	79	485	10		
		6469	−67	89	−7	67	170	8		
		6468	−61	95	−17	63	48	2		
		6466	−59	97	+10	60	145	10		
		6465	−49	107	+7	50	485	5		
		6464	−37	119	+21	42	48	6		
		6463	−29	127	−16	33	73	5		
		6462	−1	155	−11	10	61	8		
		6457	+2	158	+20	21	109	5		
		6456	+11	167	−19	21	291	35		
		6456	+19	175	−20	26	73	3		
		6452	+33	189	+25	41	339	30		
		6451	+63	219	−10	64	36	2		
		6447	+69	225	+14	70	12	5		
		6451	+72	228	−11	72	291	1		
		6445	+81	237	−17	82	24	1		
				(156)	(−)		2,932	137		
May 30..	11 33	6470	−64	79	−21	66	485	6	F	Do.
		6471	−63	80	+14	65	291	1		
		6469	−52	91	−7	53	145	7		
		6473	−48	95	−18	50	6	1		
		6468	−46	97	−17	49	24	4		
		6466	−46	97	+10	47	73	7		
		6465	−39	106	+7	40	388	6		
		6463	−14	129	−16	20	12	3		
		6457	+17	160	+20	24	97	2		
		6456	+27	170	−19	32	242	10		
		6456	+32	175	−20	37	24	1		
		6452	+46	189	+24	51	242	13		
				(143)	(−1)		2,029	61		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic				Area of spot or group	Spot count	Plate quality	Observatory
			Difference in longitude	Longitude	Latitude	Distance from center of disk				
1939	h m		°	°	°	°				
May 31	10 35	6470	−51	79	−21	54	436	21	VG	U. S. Naval.
		6471	−49	81	+13	51	242	6		
		6469	−38	92	−8	39	145	7		
		6473	−35	95	−12	37	97	7		
		6466	−34	96	+10	35	48	15		
		6468	−33	97	−17	57	12	3		
		6465	−23	107	+7	25	388	20		
		6464	−10	120	+22	25	12	6		
		6463	−3	127	−15	16	6	3		
		6472	+27	157	−22	33	12	2		
		6457	+29	159	+20	35	97	2		
		6457	+35	165	+19	40	12	3		
		6456	+39	169	−19	43	145	14		
		6452	+59	189	+25	46	339	23		
				(130)	−1		1,991	132		

Mean daily area for 31 days, 1,865.
Plate quality: F, fair; G, good; VG, very good.

PROVISIONAL SUNSPOT RELATIVE NUMBERS FOR MAY 1939

[Dependent alone on observations at Zurich]

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich, Switzerland]

May 1939	Relative numbers	May 1939	Relative numbers	May 1939	Relative numbers
1	*Ec* 163	11	101	21	*EWcc* ..
2	*aad* 157	12	*EEcc* ..	22	----------
3	*133	13	*Maac* 121	23	*a* ..
4	141	14	*aad* ..	24	*Eac* 106
5	*ab* 124	15	139	25	----------
6	115	16	118	26	97
7	*add* 133	17	*d* 93	27	*d* 104
8	*d* ..	18	*d* 79	28	*ad* 138
9	----------	19	79	29	*add* 172
10	*EMcc* 128	20	----------	30	157
				31	146

Mean, 22 days=124.7.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a group developing into a middle-sized or large center of activity. *E*, on the eastern part of the sun's disk; *W*, on the western part; *M*, on the central-circle zone.
d=Entrance of a large or average-sized center of activity on the east limb.
*=Chur.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE in charge]

By B. FRANCIS DASHIELL

The results of 690 individual upper-air observations made during May by airplanes and radiosonde in the United States, Canal Zone, Hawaii, Canada, Bermuda and the north Atlantic, are shown in tables 1 and 1a. Mean atmospheric pressures, temperatures, and resultant winds are indicated on charts VIII, IX, X, and XI. Isentropic data are shown on chart XII. Tables 2 and 3 present upper-air wind data and table 4 gives the mean altitude of the tropopause. A detailed description of these charts and tables will be found in the January 1939 issue of the MONTHLY WEATHER REVIEW.

In the lower levels where observations are made by radiosonde and airplanes, many flights reached all levels. Of the 320 airplane observations made in the United States proper, 80 percent reached 5 kilometers. But, of all the 311 radiosonde flights launched at the surface, 98 percent reached 5 kilometers. And, in the higher levels, 92, 79, and 25 percent of all flights reached 10, 15, and 20 kilometers, respectively. Means were computed for the 22-kilometer level over Nashville, Tenn., Omaha, Nebr., and Washington, D. C., while a few individual flights went even higher; 25 kilometers over St. George's, Bermuda, and 24 kilometers over Omaha, Nebr.

The May mean free-air pressure, temperature (° C.), and humidity, given in table 1a, also includes radiosonde observations for the first time from Barksdale Field, Shreveport, La., and the United States Coast Guard cutters *Champlain* and *Chelan*, when located at Halifax, Nova Scotia, or in an area at sea lying between latitudes 40° and 44° N. and longitudes 47° and 53° W.

A low mean-pressure area prevailed to the north and east of the Great Lakes, then northeastward indefinitely toward Hudson Bay and Newfoundland. However, the lowest pressure in the United States at 1.5, 3, 4, and 5 kilometers, was centered over Sault Ste. Marie, Mich. But it was found that pressures far to the east, over Halifax, Nova Scotia, were still somewhat lower. On the other hand, pressure was higher east of Halifax, Nova Scotia, for observations by Coast Guard ships at sea (table 1a) revealed pressures that were from 2 to 3 millibars higher than those recorded over Sault Ste. Marie, Mich., at all levels. The highest pressures were located in the south, being centered generally over St. George's, Bermuda, and Pensacola, Fla.

During May low mean pressure prevailed over Fargo, N. Dak., up to 1.5 kilometers; over Sault Ste. Marie, Mich., up to 16 kilometers; and over both stations from 17 to 20 kilometers. The highest mean pressure from the surface up to 1.5 kilometers predominated over St. George's, Bermuda, and then at Pensacola, Fla., up to 5 kilometers. Highest pressure then was located over St. George's, Bermuda, at 5, 6, 7, and 8 kilometers, being exceeded by Shreveport, La., at 9, 10, and 11 kilometers, and Nashville, Tenn., at 12, 13, 14, 15, 16, 17, and 18 kilometers, and Washington, D. C., at 19, 20, 21, and 22 kilometers.

The pressure differences between the LOW and HIGH areas at Halifax, Nova Scotia, and Bermuda increased steadily with altitude, varying from 7 millibars at 0.5 kilometer to 19 millibars at 5 kilometers. Similar differences between the two pressure extremes within the United States (Sault Ste. Marie, Mich., and Pensacola, Fla.), showed slightly smaller increases with altitude, ranging from 5 to 14 millibars at 0.5 to 5 kilometers, respectively.

Mean free-air temperatures (° C.) during the current month were seasonally warmer than in April at all radiosonde stations in the lower levels, but slightly colder than those recorded in April at the upper levels, with the exception of Oakland, Calif. At Fargo, N. Dak., the mean temperature at 17 kilometers (—61.8° C.) was the lowest recorded over that station since October 1938.

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In the lower levels, up to 5 kilometers, mean temperatures for May were lowest over Halifax, Nova Scotia, and highest over El Paso, Tex., at 1.5, 3, and 4 kilometers, and over Pensacola, Fla., at 5 kilometers. Above 5 kilometers, mean temperatures were highest over Shreveport, La., up to 11 kilometers; over Oakland, Calif., at 12, 13, and 14 kilometers; and over Sault Ste. Marie, Mich., from 15 to 20 kilometers, inclusive. The lowest mean temperature recorded in May in the upper air was —65.8° C. over St. George's, Bermuda, at 15 kilometers; in the United States, —64.3° C. over Nashville, Tenn., at 17 kilometers.

Mean relative humidity in the United States was lower than usual in the free air, the highest percentage being recorded at San Diego, Calif., at 0.5 and 1 kilometer; at Pensacola, Fla., at 1.5 and 2 kilometers; over Sault Ste. Marie, Mich., at 3 and 4 kilometers; over Salt Lake City, Utah, at 5 kilometers; and over Fargo, N. Dak., at 6, 7, 8, and 9 kilometers. The humidity over St. George's Bermuda, at 0.5, 1, 1.5, and 2 kilometers, was the highest reported during May. Dry air was centered in the lower levels over Omaha, Nebr., and Spokane, Wash., at 0.5 and 1 kilometer. Relative humidity ranged from 24 to 33 percent over El Paso, Tex., at 2, 2.5, 3, 4, and 5 kilometers, respectively, while above 5 kilometers the driest air was centered over Oakland, Calif., and Bermuda.

Resultant wind directions and velocities were computed during May for 115 pilot-balloon stations in the United States, Canada, Mexico, Cuba, and Bermuda. These included data for new stations at Elmira, N. Y., Mobile, Ala., San Antonio, Tex., and Springfield, Mo. Table 2 presents a list of 39 selected stations with computed resultants for all standard levels. Improvement in the number of observations made at higher levels was noted. Comparing the current month with April it was found that this increase amounted to 15, 18, and 25 percent, at 3, 4, and 5 kilometers, respectively. All stations listed in table 2 computed 5 p. m. resultants for all levels up to 2.5 kilometers; 87 percent up to 5 kilometers; 67 percent at 6 kilometers; 34 percent at 8 kilometers; 21 percent at 10 kilometers; and 13 percent at 12 kilometers.

During the current month there was a decided increase in the maximum altitudes reached by pilot balloons. It was found that 70 percent of the stations in the United States averaged at least 2.5 kilometers higher in May than in April. But in the Northwest and along the Pacific coast the maximum altitudes reached were lower in May by an average of 1.5 kilometers. At Miami, Tampa, and Jacksonville, Fla., maximum altitudes were 7 kilometers higher than in April. Highest altitudes were reached by individual ascensions at Abilene, Tex. (19,467 meters); San Antonio, Tex. (19,113 meters); and Denver, Colo. (18,597 meters). At 20 percent of all stations in the United States maximum altitudes exceeded 15 kilometers; at 70 percent elevations higher than 10 kilometers were reached; and all stations exceeded 5 kilometers during the month. The latter portion of May appeared suitable for high-altitude balloon observations—the 19th, 20th, and 21st over the Western Plains States from Texas to the Dakotas; the 23d and 24th in the Southeast; and the 30th over the Mississippi Valley. Most stations took advantage of the opportunities presented by the conditions existing on those days.

The 5 a. m. (E. S. T.) resultant wind directions at 1.5 kilometers (chart VIII), were mostly from the southwest quadrant over the eastern two-thirds of the country, except in the extreme Northeast and in Canada. Southeasterly winds occurred in 13 percent of all cases, being confined to the far South and Gulf of Mexico countries. Northwesterly wind directions, representing 36 percent of all cases, prevailed in the far North, Northwest, and along the Pacific coast, as well as in Canada. But, at 3 kilometers (chart IX), southwesterly winds predominated only in the South and Southwest, while winds from the northwest quadrant (55 percent of all cases) occurred elsewhere within the United States, as well as Canada. About 2 percent of the winds at this level were southeasterly. However, resultant winds computed from the 5 p. m. (E. S. T.) observations for both the above-mentioned levels (1.5 and 3 kilometers) showed a more definite tendency to fall within the southwest quadrant. At 1.5 and 3 kilometers, respectively, 68 and 60 percent of all directions were southwesterly.

In the lower levels, southeasterly winds ranged from 35 percent of the total at the surface to 15 percent at 1 kilometer. Above 3 kilometers, at 5 p. m., the percentage of northwest wind directions (charts X and XI, and table 2) gradually increased. At 4 kilometers the winds were equally divided between the southwest and northwest quadrants, and at 5 kilometers 60 percent of the resultants were northwesterly. Southwest winds in these levels were confined to the South, some in the far West, and generally over the Pacific coast. Wind directions above 5 kilometers were definitely from the northwest quadrant, reaching 78 percent of the total at 8 kilometers.

Resultant wind velocities during May were lower than in the preceding month. Highest velocities occurred over the Northeast, the upper Mississippi Valley, and the Southwest, at 1.5, 3, 4, and 5 kilometers. The extreme velocities for May were 9.2 meters per second at Del Rio, Tex.; 10.8 m. p. s. at Elmira, N. Y.; and 15.5 m. p. s. at Sault Ste. Marie, Mich., and Buffalo, N. Y., at 1.5, 3, 4, and 5 kilometers, respectively. In the higher levels resultant wind speeds of 17.2 and 20.6 m. p. s. were recorded over Winslow, Ariz., at 10 and 12 kilometers, respectively.

Comparing the 5 a. m. (E. S. T.) resultants (charts VIII and IX) with 5 a. m. normal resultants computed for 21 representative stations in the country, it was found that the wind directions for May at the 1.5-kilometer level departed from normal by counterclockwise orientations. These departures were pronounced at Atlanta, Ga. (the difference being 49° when rotated counterclockwise away from normal), and Oakland, Calif. (42°—counterclockwise). At 3 kilometers the counterclockwise departures were outstanding at Chicago, Ill. (39°); Medford, Oreg. (34°); Oakland, Calif. (35°); Omaha, Nebr. (33°), and Sault Ste. Marie, Mich. (27°). Velocity departures from normal during May were unimportant at 1.5 and 3 kilometers, except over Fargo, N. Dak., where the current winds were respectively 3.0 and 5.1 m. p. s. greater than normal.

Resultants based on 5 p. m. (E. S. T.) observations, when compared to existing 5 a. m. normal resultants for the surface and up to 5 kilometers, show that the May departures were in general characterized by counterclockwise rotations from normal. This was particularly noticeable at Atlanta, Ga., Cheyenne, Wyo., Chicago, Ill., Sault Ste. Marie, Mich., San Diego, Calif., and Oklahoma City, Okla. At Cheyenne, Wyo., for instance, the current winds departed from normal by 78°, 90°, 64°, 50°, 24°, and 21°, at the surface and 2, 2.5, 3, 4, and 5 kilometers, respectively. At San Diego, Calif., the departures amounted to 91°, 12°, 21°, 26°, 30°, 20°, 44°, 21°, and 33°, at the surface and up to 5 kilometers, respectively.

Stations with outstanding clockwise departures in the lower levels, and then changing to counterclockwise in the upper levels, were: Medford, Oreg., Fargo, N. Dak., Houston, Tex., Nashville, Tenn., and Seattle, Wash. At St. Louis, Mo., and Washington, D. C., large counterclockwise departures were indicated up to 2 kilometers, and then clockwise above. Resultant velocity departures from normal were large in some cases, being greater than normal at all levels over Fargo, N. Dak., Atlanta, Ga., Sault Ste. Marie, Mich., and Seattle and Spokane, Wash. This situation was outstanding at Fargo, N. Dak., and Sault Ste. Marie, Mich., above 2 kilometers. Elsewhere, velocities were lower than normal, being noticeable at Oakland, Calif., Omaha, Nebr., and Nashville, Tenn.

Resultant wind directions (based on 5 p. m., E. S. T. observations), shown in table 2, were decidedly more southerly during May than those observed in the preceding month. At all levels, particularly at Cheyenne, Wyo., Atlanta, Ga., Huron, S. Dak., Oklahoma City, Okla., Omaha, Nebr., Reno, Nev., and Winslow Ariz., the directions were generally south of those noted in April by a counterclockwise departure. The few exceptions having winds in May that were more northerly than in April, were Buffalo, N. Y., New Orleans, La., Sault Ste. Marie, Mich., Washington, D. C., Greensboro, N. C., and Brownsville, Tex. Over these stations the northerly, or clockwise, departure changes occurred at higher levels only. Velocities were lower in May than in April at all levels, particularly at Brownsville, Tex., Omaha, Nebr., and Washington, D. C. The only exceptions occurred over Winslow, Ariz., San Diego, Calif., Las Vegas, Nev., El Paso, Tex., and Sault Ste. Marie, Mich.

Table 3 shows individual maximum wind velocities reached during May. Below 2.5 kilometers, Billings, Mont., reported 47.7 m. p. s.; between 2.5 and 5 kilometers, a velocity of 58.7 m. p. s. occurred over Ely, Nev.; and above 5 kilometers, Redding, Calif., reported 80 m. p. s. (178.9 miles per hour) from the SSW on the 8th at 16.6 kilometers. This occurred at the maximum altitude reached over Redding during May, and equalled the velocity reported there in the previous month of April. It has been exceeded elsewhere only four times, but is the highest wind speed of record over any station at such a high altitude.

MEAN ISENTROPIC CHART FOR MAY 1939,[1] $\theta = 307°$

The mean isentropic chart for May shows a typical summertime pattern; a large warm, moist area extends over the western plateau and is associated with an anticyclonic tongue extending to Chicago. Over the eastern part of the country the typical eastern moist tongue is present; it originates in the Gulf and curves sharply anticyclonically over the Southeastern States. This tongue has a branch extending well over the Atlantic to Newfoundland, as shown by soundings from Coast Guard cutters and from Newfoundland Airport.

This moisture pattern does not seem to correspond well with the distribution of precipitation departures except in the northeast, where large negative departures may be explained by the downslope winds. Much better correspondence is shown with a chart showing the number of days with 0.01 inch or more of rainfall. Frequent rains near the lake regions and over southern Canada perhaps originate in lower layers and so cannot be explained by the isentropic pattern.

[1] This chart and the following discussion have been prepared by the Air Mass Section of the Meteorological Research Division.

TABLE 1.—*Mean free-air barometric pressures (P.) in mb, temperatures (T.) in °C, and relative humidities (R. H.) in percent obtained by airplanes during May 1939*

Stations and elevations in meters above sea level	Altitude (meters) m. s. l.																										
	Surface				500			1,000			1,500			2,000			2,500			3,000			4,000			5,000		
	Number of observations	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H	P.	T.	R. H.	P.	T.	R. H.
Billings, Mont. (1,090 m.)	31	890	11.0	64							848	12.9	51	798	9.5	51	751	6.1	52	706	2.3	55	623	−4.7	60	548	−11.5	59
Cheyenne, Wyo. (1,873 m.)	31	811	7.4	69										798	10.5	56	752	9.1	50	708	5.7	51	626	−1.5	54	551	−9.7	59
Chicago, Ill. (187 m.)	31	993	12.8	76	956	14.8	63	901	13.3	62	849	10.6	64	800	7.8	62	753	4.9	57	707	2.0	54	624	−3.8	49	549	−10.0	44
Coco Solo, C. Z.[1] (15 m.)	28	1,010	26.8	88	957	24.1	92	904	21.6	88	854	19.2	87	805	17.3	81	759	15.5	69	716	13.5	57	634	8.3	59			
El Paso, Tex. (1,193 m.)	31	879	19.7	27							849	21.7	24	800	18.4	23	754	14.6	23	711	10.6	22	629	1.7	28	555	−6.4	33
Lakehurst, N. J.[1] (39 m.)	29	1,011	12.3	79	957	15.1	64	902	13.2	61	850	10.4	60	800	7.4	60	752	4.3	62	707	1.1	64	624	−4.4	56	550	−10.4	57
Norfolk, Va.[1] (10 m.)	25	1,016	16.8	90	960	18.3	63	905	15.9	58	853	12.4	63	804	9.4	63	756	6.5	59	712	3.8	52	629	−1.8	45	553	−8.0	42
Pearl Harbor, T. H.[1] (6 m.)	31	1,016	21.7	80	960	19.0	80	905	15.1	82	853	12.2	79	803	10.8	67	756	9.7	43	712	7.0	34	629	1.3	23			
Pensacola, Fla.[1] (13 m.)	26	1,015	20.6	90	960	20.9	75	905	18.2	70	854	14.8	71	805	12.3	71	758	9.9	63	713	7.1	59	631	0.9	55	557	−4.9	48
St. Thomas, V. I.[1 2] (8 m.)																											
Salt Lake City, Utah (1,288 m.)	31	869	11.4	60							848	15.1	48	799	12.4	46	752	9.0	47	708	5.4	50	626	−2.3	59	550	−9.9	61
San Diego, Calif.[1] (10 m.)	29	1,015	15.9	78	958	12.5	83	903	12.6	73	850	13.2	57	801	12.1	46	754	9.4	41	710	6.3	39	628	.3	34	553	−7.0	31
Seattle, Wash.[1] (10 m.)	25	1,016	14.2	62	960	10.5	69	904	8.7	64	850	6.6	57	800	3.9	53	751	1.1	50	706	−1.5	42	621	−7.2	36			
Spokane, Wash. (597 m.)	31	945	10.0	66				901	13.8	49	848	10.6	47	799	65	52	751	2.4	54	705	−1.4	56	622	−7.8	54	546	−14.0	49

[1] Navy.

[2] Flights discontinued temporarily.

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

NOTE.—None of the means included in this table are based on less than 15 surface- or 5 standard-level observations.

TABLE 1a.—*Mean free-air barometric pressures (P.) in mb., temperatures (T.) in °C., and relative humidities (R. H.) in percent obtained by radiosondes during May 1939*

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																							
	Barksdale Field, Shreveport, La.[1] (51 m.)				St. Georges, Bermuda[2] (50 m.)				Fargo, N. Dak. (274 m.)				Nashville, Tenn. (180 m.)				Oakland, Calif. (2 m.)				Oklahoma City, Okla. (391 m.)			
	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.
Surface	22	1,007	19.4	86	26	1,013	20.4	87	31	978	11.0	66	31	994	15.3	84	31	1,016	12.3	83	31	967	16.5	80
500	22	956	19.0	77	26	962	17.9	91	31	952	14.2	62	31	958	17.2	68	31	957	10.3	82	31	954	17.3	76
1,000	22	902	17.9	69	26	907	14.9	85	31	898	14.0	57	31	903	14.5	66	31	902	12.7	58	31	900	17.9	64
1,500	22	851	15.6	63	26	855	12.2	80	31	846	11.6	56	31	851	11.5	70	31	850	11.3	51	31	849	15.2	59
2,000	22	802	12.7	60	26	805	9.7	76	31	796	8.6	55	31	801	8.7	69	31	800	8.8	45	31	800	12.1	57
2,500	22	755	9.7	57	26	758	7.8	61	31	749	5.1	56	31	754	6.1	66	31	752	5.9	43	31	753	9.0	57
3,000	22	710	6.1	54	26	713	5.4	53	31	704	2.1	57	31	709	3.8	60	31	708	3.0	41	31	709	5.9	56
4,000	20	629	.5	48	26	630	−.1	48	31	622	−4.0	58	31	626	−1.2	55	31	625	−3.2	41	31	626	−0.4	50
5,000	18	555	−5.5	44	26	556	−6.0	45	31	547	−10.3	57	31	552	−7.0	53	31	550	−9.1	40	31	552	−6.9	47
6,000	16	486	−11.9	49	26	488	−12.4	39	31	480	−17.5	56	31	485	−13.1	51	31	482	−15.9	39	31	485	−13.5	44
7,000	14	426	−17.2	50	26	427	−20.0	38	31	419	−24.8	54	31	424	−20.1	52	31	422	−23.3	39	31	424	−20.5	40
8,000	10	372	−22.5	49	26	373	−27.6	37	31	364	−32.3	53	31	370	−27.3	53	30	367	−30.8	39	31	370	−27.7	41
9,000	9	325	−29.2	50	26	323	−35.2	36	30	315	−40.1	51	31	321	−34.9	52	30	318	−38.3	39	31	321	−35.5	41
10,000	7	282	−36.9	51	26	280	−43.2	-----	30	272	−48.1	-----	31	278	−42.6	51	29	274	−45.0	-----	31	278	−43.3	-----
11,000	6	242	−43.6	-----	26	240	−51.8	-----	30	233	−54.5	-----	31	239	−50.4	-----	28	236	−50.9	-----	31	239	−50.7	-----
12,000	-----	-----	-----	-----	26	205	−59.9	-----	30	199	−58.9	-----	31	205	−56.3	-----	28	202	−54.6	-----	31	204	−56.7	-----
13,000	-----	-----	-----	-----	26	174	−64.9	-----	30	170	−60.4	-----	31	175	−59.5	-----	28	173	−56.5	-----	31	174	−59.3	-----
14,000	-----	-----	-----	-----	25	148	−65.7	-----	30	144	−59.7	-----	31	149	−60.9	-----	25	147	−57.1	-----	29	148	−59.5	-----
15,000	-----	-----	-----	-----	24	126	−65.8	-----	28	123	−60.4	-----	31	126	−62.3	-----	25	125	−57.9	-----	29	126	−60.0	-----
16,000	-----	-----	-----	-----	22	107	−65.4	-----	27	104	−61.3	-----	30	108	−63.6	-----	25	107	−59.0	-----	28	108	−61.9	-----
17,000	-----	-----	-----	-----	18	90	−64.9	-----	25	88	−61.8	-----	30	92	−64.3	-----	22	91	−60.3	-----	24	92	−63.0	-----
18,000	-----	-----	-----	-----	12	77	−62.6	-----	20	76	−61.8	-----	27	78	−63.8	-----	15	77	−60.3	-----	21	78	−63.6	-----
19,000	-----	-----	-----	-----	11	65	−59.6	-----	10	64	−60.4	-----	22	66	−61.8	-----	12	65	−60.0	-----	12	66	−63.0	-----
20,000	-----	-----	-----	-----	7	56	−55.9	-----	5	54	−59.0	-----	20	56	−58.8	-----	-----	-----	-----	-----	5	56	−60.1	-----
21,000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12	48	−56.1	-----	-----	-----	-----	-----	-----	-----	-----	-----
22,000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	5	40	−51.1	-----	-----	-----	-----	-----	-----	-----	-----	-----

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																			
	Omaha, Nebr. (300 m.)				Sault Ste. Marie, Mich. (221 m.)				Washington, D. C.[3] (13 m.)				Halifax, Nova Scotia[4] (5 m.)				At sea[4] (5 m.)			
	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.	Number of observations	P.	T.	R. H.
Surface	31	977	15.8	67	31	987	6.4	87	29	1,015	14.6	80	18	1,015	3.7	-----	30	1,017	8.3	-----
500	31	955	17.4	58	31	955	7.4	80	29	957	14.6	70	18	955	2.5	-----	30	957	8.3	-----
1,000	31	901	16.2	53	31	899	7.2	73	29	902	12.4	64	18	897	1.2	-----	30	901	7.6	-----
1,500	31	849	13.5	51	31	845	5.6	71	29	849	9.4	64	18	843	−1.1	-----	30	847	6.2	-----
2,000	31	800	10.5	50	31	795	3.4	68	29	800	6.3	63	18	792	−3.5	-----	30	797	4.4	-----
2,500	31	752	7.5	52	31	747	1.0	65	29	752	3.3	63	18	743	−5.7	-----	30	749	2.2	-----
3,000	31	708	4.4	53	31	702	−1.7	65	29	707	.7	60	18	697	−7.6	-----	30	704	−.5	-----
4,000	31	626	−2.0	55	31	618	−7.4	60	29	624	−4.2	51	18	612	−12.4	-----	30	621	−5.8	-----
5,000	30	551	−8.0	55	31	543	−13.4	53	29	548	−9.7	48	18	537	−17.9	-----	30	546	−11.6	-----
6,000	30	484	−14.6	52	31	476	−19.8	51	29	481	−15.9	46	18	469	−24.1	-----	30	478	−17.7	-----
7,000	30	423	−21.8	49	31	415	−26.8	48	29	420	−22.9	45	18	408	−30.8	-----	29	418	−23.9	-----
8,000	30	369	−29.4	46	31	361	−34.1	47	29	366	−29.8	44	17	353	−37.9	-----	28	363	−31.3	-----
9,000	30	319	−37.3	45	30	312	−41.4	46	29	317	−37.4	45	16	305	−45.3	-----	28	315	−38.2	-----
10,000	29	276	−44.9	-----	30	268	−48.4	-----	29	274	−44.7	-----	15	262	−51.7	-----	28	271	−44.9	-----
11,000	29	237	−51.8	-----	29	230	−54.9	-----	29	235	−51.3	-----	13	224	−55.5	-----	27	233	−51.4	-----
12,000	29	203	−56.3	-----	28	196	−57.7	-----	29	202	−55.9	-----	8	192	−55.4	-----	26	200	−56.8	-----
13,000	29	173	−57.6	-----	28	168	−57.3	-----	29	172	−59.1	-----	7	164	−54.7	-----	26	171	−58.9	-----
14,000	28	147	−57.5	-----	28	143	−57.2	-----	29	147	−60.6	-----	7	140	−54.6	-----	26	146	−58.3	-----
15,000	27	126	−58.8	-----	26	122	−57.8	-----	27	126	−61.2	-----	5	120	−54.6	-----	24	125	−58.3	-----
16,000	26	107	−60.2	-----	23	104	−58.7	-----	26	107	−61.9	-----	-----	-----	-----	-----	22	106	−58.4	-----
17,000	24	91	−61.0	-----	22	88	−59.1	-----	23	91	−62.4	-----	-----	-----	-----	-----	21	91	−58.2	-----
18,000	20	77	−60.7	-----	17	75	−58.9	-----	18	78	−61.7	-----	-----	-----	-----	-----	18	78	−57.8	-----
19,000	14	66	−60.0	-----	11	64	−58.0	-----	16	67	−60.6	-----	-----	-----	-----	-----	12	67	−57.3	-----
20,000	13	56	−58.6	-----	5	54	−57.8	-----	14	57	−59.7	-----	-----	-----	-----	-----	9	57	−57.0	-----
21,000	11	48	−56.8	-----	-----	-----	-----	-----	7	48	−58.8	-----	-----	-----	-----	-----	-----	-----	-----	-----
22,000	9	41	−54.4	-----	-----	-----	-----	-----	5	40	−58.2	-----	-----	-----	-----	-----	-----	-----	-----	-----

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

[1] Army.
[2] Operated by Massachusetts Institute of Technology.
[3] Navy.
[4] Soundings made by U. S. C. G. cutters *Champlain* and *Chelan* of International Ice Patrol. The observations at sea were made in an area extending from latitudes 40° to 44° N. and from longitudes 47° to 53° W. Humidity data will be published at a later date.

NOTE.—None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

Number of observations refers to pressure only as temperature and humidity data are missing for some observations at certain levels, also, the humidity data are not used in daily observations when the temperature is below −40° C.

TABLE 2.—*Free-air resultant winds based on pilot-balloon observations made near 5 p. m. (E. S. T.) during May 1939*

[Directions given in degrees from North (N=360°, E=90°, S=180°, W=270°)—Velocities in meters per second (superior figures indicate number of observations)]

Altitude (meters) m. s. l.	Abilene, Tex. (537 m.)		Albuquerque, N. Mex. (1,554 m.)		Atlanta Ga. (302 m.)		Billings, Mont. (1,095 m.)		Boise, Idaho (850 m.)		Brooklyn, N. Y. (15 m.)		Brownsville, Tex. (7 m.)		Buffalo, N. Y. (220 m.)		Burlington, Vt. (132 m.)		Charleston, S. C. (18 m.)		Cheyenne, Wyo. (1,873 m.)		Chicago, Ill. (192 m.)		Cincinnati, Ohio (157 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	153	3.4[21]	247	2.9[21]	253	1.6[29]	333	2.2[21]	301	2.5[21]	186	4.3[29]	135	5.2[31]	257	3.6[31]	257	1.0[31]	154	1.6[31]	207	0.6[30]	170	0.4[31]	241	1.1[29]
500					245	2.2[29]					238	4.7[29]	138	7.3[31]	260	5.4[31]	275	2.3[31]	184	4.0[29]			209	1.3[31]	239	2.8[31]
1,000	155	4.3[31]			235	3.1[29]			294	3.8[31]	271	5.5[29]	150	5.9[30]	262	7.5[30]	277	4.1[30]	206	2.8[28]			238	3.1[31]	245	2.8[31]
1,500	172	4.1[31]			236	3.7[29]	300	3.0[30]	305	3.8[31]	283	6.9[29]	149	3.7[27]	261	7.9[29]	273	6.4[29]	239	2.8[28]			247	4.0[31]	246	3.0[28]
2,000	203	5.3[27]	245	3.8[31]	237	4.2[27]	284	2.6[29]	305	3.4[31]	288	8.1[27]	148	1.0[31]	269	9.0[27]	273	8.4[27]	270	3.5[28]	190	1.2[30]	254	4.9[29]	275	3.4[28]
2,500	228	5.8[32]	238	4.1[31]	256	4.5[28]	262	2.8[29]	301	2.0[29]	294	9.0[28]	332	0.2[30]	283	8.3[28]	271	8.4[30]	271	4.2[28]	217	2.2[30]	271	4.8[29]	269	4.3[29]
3,000	238	6.2[33]	245	4.1[31]	264	4.5[28]	259	5.2[33]	258	2.7[29]	297	9.2[29]	293	0.8[18]	296	8.7[17]	282	8.8[16]	260	5.3[34]	236	2.9[30]	284	4.7[28]	276	5.6[19]
4,000	258	6.6[32]	260	6.7[21]	259	5.0[30]	279	6.4[18]	255	3.1[32]	307	12.8[15]	310	3.3[13]	300	12.7[10]			276	7.2[30]	261	5.7[37]	272	5.5[18]	303	7.0[14]
5,000	281	8.4[21]	259	10.2[29]	280	6.1[16]	287	8.5[18]	238	5.6[18]	302	11.3[10]	295	5.2[21]	303	15.5[10]			258	7.0[16]	258	7.9[33]				
6,000	282	9.0[17]	255	12.2[26]	271	4.7[13]	288	7.0[14]	244	6.3[10]			286	8.2[16]							253	10.2[16]				
8,000	295	7.5[12]	258	13.0[21]			294	9.0[11]																		
10,000	297	9.9[11]	250	18.8[18]																						
12,000	275	11.5[11]	256	20.6[12]																						

Altitude (meters) m. s. l.	El Paso, Tex. (1,196 m.)		Fargo, N. Dak. (283 m.)		Greensboro, N. C. (271 m.)		Havre, Mont. (766 m.)		Houston, Tex. (21 m.)		Huron, S. Dak. (393 m.)		Las Vegas, Nev. (570 m.)		Little Rock, Ark. (82 m.)		Medford, Oreg. (410 m.)		Miami, Fla. (10 m.)		Minneapolis, Minn. (261 m.)		Nashville, Tenn. (194 m.)		New Orleans, La. (19 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	269	3.2[31]	293	1.4[21]	200	2.8[30]	280	3.3[29]	139	4.3[30]	264	0.5[21]	210	3.0[21]	149	0.9[21]	298	2.6[29]	112	4.5[21]	223	1.8[29]	201	1.5[29]	142	0.8[29]
500			291	1.5[21]	211	3.9[29]			142	4.5[30]	307	7.5[21]			188	1.4[21]	300	2.6[29]	116	5.6[21]	223	2.2[29]	210	1.5[30]	183	1.9[29]
1,000			274	2.2[31]	225	4.6[29]	274	4.8[29]	152	2.2[29]	266	0.5[21]	221	3.0[21]	212	2.5[29]	310	2.5[29]	131	3.1[29]	220	3.1[29]	240	2.2[29]	212	2.0[28]
1,500	253	4.8[31]	267	3.7[30]	245	3.9[30]	268	5.7[28]	182	0.6[29]	225	1.8[30]	214	3.5[21]	222	3.1[29]	291	1.6[29]	162	1.5[26]	234	4.6[28]	238	3.4[29]	245	2.2[28]
2,000	255	5.4[31]	261	4.7[30]	273	3.9[26]	271	6.5[29]	250	0.9[28]	233	3.7[30]	221	2.8[21]	246	2.9[33]	221	1.6[29]	237	2.7[33]	255	5.5[26]	250	3.1[27]	306	2.0[33]
2,500	257	5.2[31]	248	7.0[34]	291	4.3[27]	271	7.4[28]	264	0.8[33]	250	4.8[30]	241	3.3[21]	274	3.0[32]	199	2.8[29]	253	2.6[33]	266	6.7[28]	251	3.7[27]	305	2.7[19]
3,000	260	5.8[30]	261	8.0[32]	280	4.4[21]	259	5.8[16]	277	2.3[32]	260	5.4[29]	246	4.5[21]	290	4.1[31]	211	3.6[27]	241	2.8[30]	276	6.9[32]	247	2.9[31]	324	4.3[17]
4,000	259	7.2[30]	269	10.8[19]	284	5.3[16]	258	9.0[13]	292	1.6[14]	278	7.2[21]	248	5.2[27]	299	4.6[17]	237	4.0[18]	239	2.9[16]	286	10.0[17]	328	3.7[17]	328	5.8[18]
5,000	259	9.6[26]	273	12.9[13]	275	5.7[14]			284	3.0[16]	288	8.3[20]	253	6.2[27]	285	4.6[18]	242	5.7[16]	251	2.3[14]	282	10.6[14]	334	6.2[13]	315	6.4[16]
6,000	266	11.5[24]	281	14.0[10]	303	8.4[10]			293	5.3[13]	280	8.8[16]	256	7.6[24]	291	5.7[13]	233	8.4[13]	257	1.3[10]	283	13.2[10]			307	7.9[10]
8,000	257	11.7[15]									290	9.5[13]	284	12.0[17]	286	6.8[10]	240	10.9[11]								
10,000											294	7.8[12]	266	18.7[11]												
12,000											265	7.4[12]														
14,000											285	6.4[11]														

Altitude (meters) m. s. l.	Oakland, Calif. (8 m.)		Oklahoma City, Okla. (402 m.)		Omaha, Nebr. (306 m.)		Reno, Nev. (1,346 m.)		St. Louis, Mo. (170 m.)		Salt Lake City, Utah. (1,294 m.)		San Diego, Calif. (15 m.)		San Juan, P. R. (16 m.)		Sault Ste. Marie, Mich. (198 m.)		Seattle, Wash. (14 m.)		Spokane, Wash. (603 m.)		Washington, D. C. (10 m.)		Winslow, Ariz. (1,488 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	261	5.7[30]	168	3.9[33]	181	2.1[21]	203	1.5[21]	171	1.7[30]	303	1.3[21]	280	4.3[21]	91	6.5[31]	262	2.2[29]	274	2.8[21]	237	3.0[21]	208	0.9[21]	242	4.9[21]
500	272	5.2[30]	172	4.1[29]	183	1.9[21]			174	2.2[29]			289	3.7[31]	102	9.3[21]	264	2.6[30]	253	2.0[21]			227	2.2[21]		
1,000	276	3.4[29]	175	3.7[30]	185	2.2[21]			188	2.4[29]			303	2.6[27]	119	7.5[21]	239	3.2[27]	229	2.8[21]	237	3.7[21]	243	3.7[30]		
1,500	258	2.8[29]	193	4.1[29]	208	2.3[21]	216	1.8[21]	226	2.1[27]	313	1.5[21]	292	3.2[28]	118	6.0[30]	284	4.8[27]	221	2.8[28]	235	3.5[21]	270	4.8[29]		
2,000	256	2.1[25]	221	4.5[27]	235	2.8[21]	225	2.6[21]	236	2.9[27]	276	1.8[21]	277	3.0[28]	108	4.6[28]	288	7.8[24]	197	3.1[23]	226	4.5[29]	279	6.4[27]	233	4.9[21]
2,500	249	2.5[28]	234	4.8[26]	273	3.1[20]	222	2.3[21]	283	2.6[28]	265	2.4[21]	273	4.8[23]	103	3.5[14]	301	9.4[19]	214	3.7[23]	231	4.5[23]	290	6.4[30]	235	4.4[21]
3,000	253	2.3[28]	245	5.4[23]	280	4.0[28]	228	2.7[21]	298	5.4[21]	258	2.3[20]	268	5.7[28]			304	11.7[16]	214	5.6[19]	242	5.7[22]	294	6.4[24]	233	4.4[21]
4,000	256	3.9[27]	262	6.1[20]	281	6.5[28]	227	4.6[21]	317	4.4[16]	253	3.3[23]	263	8.1[23]			310	15.5[13]	222	7.6[16]	253	7.3[19]	306	8.6[18]	248	6.3[19]
5,000	258	5.2[24]	277	6.0[19]	276	8.0[32]	235	5.7[28]	313	6.4[11]	251	5.5[20]	260	11.4[21]					235	9.3[12]	249	8.3[13]	301	9.1[13]	250	8.2[20]
6,000	267	6.8[18]	277	6.8[16]	285	8.6[21]	281	4.8[32]			269	5.1[17]	263	12.5[20]											249	11.8[17]
8,000	306	5.9[10]	289	7.3[12]	266	7.3[16]	281	6.5[17]																	252	15.5[19]
10,000			270	10.2[13]	265	7.0[18]	282	14.9[13]																	265	17.2[14]
12,000					272	9.6[11]																			266	20.6[11]

TABLE 3.—*Maximum free-air wind velocities (M. P. S.) for different sections of the United States based on pilot-balloon observations during May 1939*

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m. s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m.) m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m.) m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m.) m. s. l.	Date	Station
Northeast [1]	34.7	WSW	2,200	10	Syracuse, N. Y.	39.0	WNW	4,180	18	Syracuse, N. Y.	56.0	NW	14,920	30	Cleveland, Ohio.
East-Central [2]	29.8	WSW	770	28	Cincinnati, Ohio	31.8	N	5,000	2	Nashville, Tenn.	38.0	W	10,290	5	Knoxville, Tenn.
Southeast [3]	25.7	W	2,080	9	Jacksonville, Fla.	31.0	W	5,000	1	Charleston, S. C.	43.6	WNW	6,570	16	Tampa, Fla.
North-Central [4]	31.8	W	1,910	10	Detroit, Mich.	35.2	NW	4,640	17	Sault Ste. Marie, Mich	37.2	N	12,040	15	Huron, S. Dak.
Central [5]	33.9	SSW	1,230	6	Wichita, Kans.	33.6	WNW	4,660	10	Indianapolis, Ind.	50.0	SSW	9,440	7	Omaha, Nebr.
South-Central [6]	32.7	SW	1,730	23	Amarillo, Tex.	29.0	W	4,560	8	Dallas, Tex.	73.0	WSW	18,350	20	Abilene, Tex.
Northwest [7]	47.7	WNW	1,700	19	Billings, Mont.	48.3	W	3,950	9	Butte, Mont.	49.0	NNE	11,220	5	Medford, Oreg.
West-Central [8]	31.0	SSW	2,500	21	Modena, Utah	58.7	SSW	3,080	21	Ely, Nev.	80.0	SSW	16,630	8	Redding, Calif.
Southwest [9]	33.7	SW	2,280	22	Las Vegas, Nev.	33.0	NW	5,000	23	Sandberg, Calif.	60.8	SW	10,970	13	Albuquerque, N. Mex.

[1] Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and northern Ohio.
[2] Delaware, Maryland, Virginia, West Virginia, southern Ohio, Kentucky, eastern Tennessee, and North Carolina.
[3] South Carolina, Georgia, Florida, and Alabama.
[4] Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.
[5] Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.
[6] Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except El Paso), and western Tennessee.
[7] Montana, Idaho, Washington, and Oregon.
[8] Wyoming, Colorado, Utah, northern Nevada, and northern California.
[9] Southern California, southern Nevada, Arizona, New Mexico, and extreme west Texas.

TABLE 4.—*Mean altitudes and temperatures of significant points identifiable as tropopauses during May 1939, classified according to the potential temperatures (10-degree intervals between 290° and 399° A.) with which they are identified (based on radiosonde observations)*

Potential temperatures	Fargo, N. Dak.			Nashville, Tenn.			Oakland, Calif.			Oklahoma City, Okla.			Omaha, Nebr.			Sault Ste. Marie, Mich.			St. Georges, Bermuda			Washington, D. C.		
	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.
290-299																								
300-309																6	6.7	−47.0				1	6.9	−42.0
310-319	7	9.7	−54.6				3	7.8	−33.3				2	10.0	−55.5	6	9.3	−53.0				3	9.0	−48.3
320-329	13	10.8	−57.5	10	9.8	−47.1	16	9.5	−44.5	6	11.3	−52.8	6	10.1	−49.7	17	10.7	−57.4	8	9.0	−40.1	9	10.5	−58.1
330-339	21	11.8	−61.6	16	11.5	−56.8	17	11.2	−54.0	18	11.4	−55.8	18	11.3	−55.2	16	11.6	−58.2	25	12.0	−61.1	10	11.5	−60.5
340-349	8	12.5	−60.9	23	12.6	−60.6	12	12.0	−55.6	20	12.3	−52.2	18	12.4	−59.4	10	12.3	−59.8	17	13.1	−65.9	9	13.0	−64.7
350-359	5	13.0	−61.4	5	13.4	−62.6	7	12.8	−57.0	8	13.2	−60.1	5	13.0	−58.8	4	12.8	−58.8	5	13.9	−68.0	3	13.6	−64.0
360-369	2	14.2	−64.5	5	14.3	−64.4	2	13.6	−58.0	7	13.6	−59.9	1	13.9	−64.0	6	13.5	−59.2	5	14.3	−66.4	1	11.7	−54.0
370-379	2	15.2	−69.5	2	15.8	−67.5	3	14.0	−57.0	2	13.9	−55.0	4	14.4	−61.2	4	14.5	−61.5	2	15.4	−70.0	1	14.4	−59.0
380-389	7	15.2	−63.4	1	16.0	−71.0	1	13.7	−51.0				3	15.5	−63.3	3	14.6	−59.3	3	16.0	−73.3	1	16.4	−73.0
390-399	2	15.8	−60.0	3	14.9	−61.3	1	14.8	−56.0	1	15.9	−63.0	1	15.8	−63.0	2	15.6	−63.4	1	15.9	−66.0			
All (weighted means)		12.2	−60.4		12.3	−58.4		11.2	−51.6		12.3	−55.5		12.2	−57.3		11.5	−54.7		12.6	−61.5		11.7	−59.9
Mean potential temperature		342.4			345.5			339.5			346.0			344.8			338.9			341.6			336.5	

RIVERS AND FLOODS

[River and Flood Division, MERRILL BERNARD in charge]

By THOMAS S. SOUTHWICK

Floods during April and May 1939 were numerous throughout the eastern part of the United States and the Mississippi River system with the greater number occurring in April. Flooding was generally confined to moderate stages although a few extremes were recorded. Damage to property was small although there was an appreciable amount of damage to prospective crops, due to the occurrence of floods during the planting season.

The greater number of floods resulted from a widespread disturbance which traversed the Middle West and the Ohio Valley during the period April 15–17. This disturbance was characterized by marked instability with attendant thunderstorms, tornadoes, and high intensities of rainfall, especially in Arkansas.

St. Lawrence drainage.—Abundant rainfall in the Great Lakes region during April maintained the streams at moderate to high stages. A rain of about an inch and a half on April 17 caused the Red Cedar and Grand Rivers in Michigan to go over their banks. Flood stages prevailed from 4 days to a week. Damage was slight.

Atlantic Slope drainage.—Snow surveys during the middle of April in the headwater areas of the Connecticut and Merrimack Rivers indicated a water content ranging from a few inches to as much as 15 inches. This snow cover prevailing so late in the season had for some weeks constituted a flood menace which was causing some anxiety in New England.

The run-off from the snow occurred in the latter part of April, fortunately without serious consequences. The rainfall for April was above normal with the greater portion falling in the first 3 weeks of the month. There were no periods of abnormally high temperatures so that the run-off was characterized by a gradual rise to moderate stages rather than to sudden and disastrously high stages as had been feared. An exception was the Pemigewasett River at Plymouth, N. H., where the stage rose suddenly from 3.2 feet on the morning of April 19 to 11.2 feet (flood stage 11 feet) during the afternoon of April 20.

Stages on the Merrimack and Connecticut Rivers were generally above flood stage on April 20. On the Merrimack River, the period above flood stage was only 2 days, while on the Connecticut the flood period extended into May at a number of stations.

Streams remained high during the first 2 weeks of May with flood stage being reached at North Stratford, N. H., and White River Junction, Vt. There was no damage reported in these overflows.

Rainfall during April over the South Atlantic States was about half of normal, but the rivers were still full in their lower reaches from the copious precipitation of February and March. The occasional rains of early April sufficed to raise rivers above flood stage on the Cape Fear, Savannah, and Altamaha Rivers during the early part of the month. Flood stages were again attained in early May as the result of rains at the close of April on the Roanoke and Cape Fear Rivers. All stages were moderate with no damage reported.

Stages slightly above flood stage were reached on the Santee River during April and May as the result of the release of impounded water.

East Gulf of Mexico drainage.—Rainfall was deficient during April but streams were rising from the precipitation of the previous month and moderate flood stages occurred early in April on the Apalachicola, Chickasaway, Tombigbee, and Pearl Rivers. Stages reached were considerably below those of February and March. The only damage reported was in the Pearl River drainage where losses amounting to $3,450 occurred. Damage elsewhere was confined to the delay in planting crops.

Rainfall was above normal during May with most of the precipitation occurring in the last 2 weeks of the month. Rivers rose, but, except at Aberdeen, Miss., and Lock No. 3 on the Tombigbee River, flood stages had not yet been attained at the close of May.

Upper Mississippi Basin.—The flood of March in the Wisconsin and Illinois Rivers continued into April with falling stages. The Mississippi River was above flood stage early in the month as a result of these floods.

A rain of about an inch and a half during April 5–6 over the Meremec River caused minor flooding on April 7–8.

Rivers went above flood stage in the middle of April as the result of the widespread disturbance which traversed the region during the period April 15–17. Storm totals were about 3 inches. The Illinois, Bourbeuse, and Meremec Rivers were above flood stage by the 17th or 18th of April. Crests on the lower Illinois River were not reached until late in the month and additional rains caused flood stages to continue into May.

The overflow on the Mississippi River was the result of the run-off from these floods adding to the river already at high stage from the floods of March. Stages were moderate.

There was an appreciable damage reported, as follows: On the Wisconsin River, 3,400; the Meremec River, $62,500; and the Mississippi River, $13,575. Most of the damage was to prospective crops.

Missouri Basin.—Stages slightly above flood stage occurred on the Missouri River early in April as a result of the Spring break-up.

A comparison of crest stages during the Spring break-up in 1938 and 1939 as compiled by the official in charge, Weather Bureau Office, Kansas City, follows:

	Flood stage	Crest 1938	Stage 1939		Flood stage	Crest 1938	Stage 1939
	Feet	*Feet*	*Feet*		*Feet*	*Feet*	*Feet*
Bismarck, N. Dak.	19	20.5	22.2	Omaha, Nebr.	19	18.4	19.4
Pierre, S. Dak.	15	12.9	14.2	Nebraska City, Nebr.	15	16.6	17.1
Yankton, S. Dak.	12	9.2	10.1	St. Joseph, Mo.	17	13.7	15.8
Sioux City, Nebr.	19	13.2	14.4	Kansas City, Mo.	22	14.7	17.4

The total damage reported from this rise was $165,825 and was mostly damage to prospective crops.

The storm of April 15–17 resulted in overflows of mild proportions in the Big Blue, Grand, Gasconade Rivers, and the Missouri River below Hermann, Mo. Damage of $3,500 to bridges and highways was reported in the Big Blue River drainage; in the lower Missouri the damage is estimated at $86,500.

Ohio Basin.—Flood stages occurred early in April at a number of stations on the Green and Ohio Rivers. These rises were a continuation of the floods of February. The crest from this flood reached Cairo, Ill. on April 11, with a crest stage of 41.5 feet.

Another flood occurred in the Ohio Valley as a result of the storm of April 15–17. The flood area embraced the

Ohio River, its northern tributaries and the headwater areas in West Virginia. The Kentucky, Cumberland, and Tennessee Rivers did not experience flood stages.

This second Ohio flood was caused by a 3-inch rain, most of which fell within a 36-hour period. This resulted in rapid rises of generally shorter duration than the February flood. In fact, this flood was marked by less severity in all respects and less damage resulted than in the former flood. At a number of points, however, the January–February stages were exceeded.

The total damage reported in the Ohio River Valley for this flood is $848,801 of which the greater part is damage to prospective crops and the suspension of farming operations.

Following are abstracts of reports submitted by the River district centers of the Weather Bureau:

Pittsburgh, Pa.—W. S. Brotzman, official in charge:

The West Fork River at Weston, W. Va., rose from a stage of 2.5 feet on the morning of April 15 to 20.2 feet, or 5.2 feet above flood stage, by 10:30 p. m. of the 16th. This was the highest stage since 1890. Damage on this river was confined to flooding of cellars in Weston and Clarksburg, and some submergence of highways.

Practically all of the Tygart was impounded in Tygart Dam so that the Monongahela River did not reach flood stages above the mouth of the Cheat River. The heavy output of the Cheat added to high stages in the Monongahela River caused flood stages in the lower Monongahela River. No damge was done except for suspension of navigation while water was over the lock walls at Lock 5.

Parkersburg, W. Va.—S. S. Schworm, official in charge:

The rise in the Little Kanawha River was one of the most rapid ever known, producing a runout current at Parkersburg that was probably the swiftest of record. The crest at Glenville, W. Va., was 0.6 foot less than the highest of record (in 1926). The crest at Creston was 1.2 feet above the highest of record (previous highest stage, 32.0 feet March 14, 1918).

At Glenville, W. Va., practically all business houses were flooded. Other river towns above and below Glenville reported highest inundation of record.

Cincinnati, Ohio.—W. C. Devereaux, official in charge:

This flood was confined mainly to the Ohio River. At the time of the heavy rains, the Ohio River in this district was at about normal stage, while the tributaries were relatively low.

Reports on the morning of April 16 showed substantial rises with the Ohio River rising at the rate of five to seven-tenths of a foot per hour. Flood stages were reached in only three of the tributaries, namely, the Elk at Clay, W. Va.; the Little Miami at Kings Mills, Ohio; and the Licking at Falmouth, Ky.

As compared with the February 1939 flood, the crests on the Ohio River were from 0.2 to 6.3 feet lower from Cincinnati to Dam No. 28, at Dam 37 it was the same, at Dam 38 it was 0.1 foot higher and at Dam 39, it was 0.6 foot lower.

The damage along the three tributary streams was small, while along the Ohio it was less than in the February 1939 flood.

Louisville, Ky.—J. L. Kendall, official in charge.

Although the crest at Cincinnati was almost the same as in the February rise, the crest at Louisville was 1.5 feet less because the flooding in this district was not supported by any rise of consequence in the Kentucky River or by heavy local rainfall. The resulting damage was not great, being largely confined to delay in planting of crops.

Evansville, Ind.—E. E. Unger, official in charge:

The crest stage at Evansville was 43.4 feet on April 23. This made the third successive month that the river had passed the 40-foot mark. Although this flood was of considerably shorter duration than in February–March 1939, the silt deposit was very heavy, though not as heavy as after last month's flood.

The April 1939 high water was a major flood, but due to the fact that it followed so closely the floods of February–March 1939, and the great 1937 flood, the damage was at a minimum. Principal damage was to crops and suspension of farming operations.

White and Arkansas River Basins.—Flood stages continued into April on the lower reaches of the White River, with falling stages, the crests having been reached in March. Heavy rain on April 5–6 caused mild overflows on the lower Black River and prolonged the period of high stages on the lower White River. Slight flooding also occurred as a result of this storm on the North Canadian and Poteau Rivers in Oklahoma and on the Petit Jean River in Arkansas with only slight damage.

The general storm of April 16–17 was accompanied by very heavy precipitation, the 2-day storm totals for a few points being as follows: Black Rock, Ark., 4.42 inches; Calico Rock, Ark., 4.20 inches; Batesville, Ark., 4.54 inches; Poteau, Okla., 6.56 inches; Danville, Ark., 10.04 inches. Overflows occurred on the Black, White, Poteau, and Petit Jean Rivers. The crest stage at Danville, Ark., on the Petit Jean River was the highest of record. Damage on the Black River amounted to $500. On the Poteau River the damage reported was $12,300. Damage figures are not available for the Petit Jean.

Red River Basin.—The flood situation was similar to that prevailing in the White and Arkansas Basins. A few stations were still in flood from the previous month. The rain of April 5–6 caused overflows of small proportions on the Ouachita, Little, and Sulphur Rivers. The Black River at Jonesville, La., remained at slightly above flood stage from March until May 2.

The April 16–17 storm was not characterized by the excessive amounts found to the north except in the Saline River drainage where Benton, Ark., had a storm total of 5.53 inches. Moderate stages were reached, but no appreciable damage occurred.

Lower Mississippi Basin.—Flood stages prevailed along the Mississippi River and its tributaries throughout much of April and May, as a result of widespread floods throughout the Mississippi River system. augmented by the local run-off from the flood-producing rains of the period. Heights above flood stage were only nominal, but the overflow did some damage to prospective crops. The greatest reported was in the Memphis area where damage amounted to $569,150.

West Gulf of Mexico drainage.—On the Trinity River, flood stages were reached as a result of the rains of April 16 and 17. Flooding was slight with damage reported at $2,375.

Slight flooding occurred on the Nueces River at Cotulla, Tex., on May 8 and May 16–17. No damage resulted. Flood stage was slightly exceeded at Brownsville, Tex., on the Rio Grande for a few hours on May 16 with no damage.

Table of flood stages during April and May 1939

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ST. LAWRENCE DRAINAGE					
Lake Michigan					
Red Cedar:	*Feet*			*Feet*	
Williamston, Mich.	6	Apr. 18	Apr. 21	7.2	Apr. 19
East Lansing, Mich.	8	18	21	8.3	19
Grand: Eaton Rapids, Mich.	5	18	24	5.5	19–20
ATLANTIC SLOPE DRAINAGE					
Connecticut:					
North Stratford, N. H.	10	May 9	May 9	10.0	May 9
South Newbury, Vt.	18	Apr. 20	3	26.5	Apr. 24
		May 5	13	22.8	May 11
White River Junction, Vt.	18	Apr. 21	Apr. 30	20.9	Apr. 26
Walpole, N. H.	25	20	28	30.9	23
Montague City, Mass.	28	20	28	31.5	23
Holyoke, Mass.	9	23	26	9.7	23–24
Hartford, Conn.	16	20	May 3	21.8	25
Pemigewasett: Plymouth, N. H.	11	20	Apr. 20	11.2	20
Merrimack:					
Franklin Junction, N. H.	14	20	21	16.0	20
Concord, N. H.	12	21	22	13.0	21
Roanoke:					
Weldon, N. C.	31	May 3	May 4	34.0	May 3
Williamston, N. C.	10	7	10	10.3	9
Neuse:					
Neuse, N. C.	14	4	6	16.5	5
Smithfield, N. C.	14	6	7	14.0	6–7
Cape Fear: Lock No. 2, Elizabethtown, N. C.	20	Apr. 1	Apr. 1	20.2	Apr. 1
		May 4	May 5	21.4	May 5
Santee:					
		Mar. 30	Apr. 9	13.4	Apr. 2
		Apr. 13	15	12.4	14
		19	23	12.7	21–22
Rimini, S. C.	12	27	30	12.6	29
		May 4	May 7	12.6	May 5–6
		11	14	12.7	14
		Mar. 30	Apr. 10	12.8	Apr. 4
		Apr. 21	24	12.2	23
		29	May 1	12.1	30–May 1
Ferguson, S. C.	12	May 7	7	12.0	7
		13	15	12.2	14
Savannah: Clyo, Ga.	11	Apr. 4	Apr. 16	14.0	Apr. 9
Altamaha: Charlotte, Ga.	12	5	12	14.1	9
EAST GULF OF MEXICO DRAINAGE					
Apalachicola: Blountstown, Fla.	15	Mar. 30	13	19.8	4
Tombigbee:					
Aberdeen, Miss.	34	Apr. 1	2	35.1	1
		May 26	May 27	34.4	May 26
Lock No. 4, Demopolis, Ala.	39	Apr. 1	Apr. 12	43.2	Apr. 4
		Mar. 31	16	45.8	4
Lock No. 3, Ala.	33	Apr. 20	23	36.4	21
		May 31	(1)		
Lock No. 2, Ala.	46	Apr. 3	7	46.9	Apr. 5–6
Lock No. 1, Ala.	31	3	15	32.9	7–8
Chickasawhay: Enterprise, Miss.	20	Mar. 31	1	20.8	1
Pearl:					
Jackson, Miss.	18	30	10	23.1	6
Monticello, Miss.	15	30	3	17.4	Mar. 31
Columbia, Miss.	17	Apr. 1	2	17.5	Apr. 1–2
Pearl River, La.	12	2	16	15.0	5
MISSISSIPPI SYSTEM					
Upper Mississippi Drainage					
Wisconsin: Portage, Wis.	17	Mar. 29	1	18.2	Mar. 30
Illinois:					
Peru, Ill.	17	Apr. 19	23	17.2	Apr. 21
Havana, Ill.	14	Mar. 12	2	17.9	Mar. 20
		Apr. 18	May 4	16.0	Apr. 27
Beardstown, Ill.	14	Mar. 11	Apr. 4	20.3	Mar. 20, 21
		Apr. 18	May 10	17.7	Apr. 26–28
Bourbeuse: Union, Mo.	12	18	Apr. 19	13.6	19
Meramec:					
Sullivan, Mo.	11	7	7	12.0	7
		17	19	26.0	17
Pacific, Mo.	11	8	8	13.6	8
		17	21	22.5	19
Valley Park, Mo.	14	8	8	15.5	8
		17	21	27.2	19
Mississippi:					
Muscatine, Iowa	15	9	11	15.1	10
Keokuk, Iowa	12	10	19	13.1	17
Quincy, Ill.	14	11	20	17.2	18
Hannibal, Mo.	13	9	22	17.8	18
Grafton, Ill.	18	17	23	22.0	20
Alton, Ill.	21	17	23	25.7	20
St. Louis, Mo.	30	20	20	30.1	20
Chester, Ill.	27	18	24	30.7	21
Cape Girardeau, Mo.	32	18	26	36.1	22

Table of flood stages during April and May 1939—Continued

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI SYSTEM—continued					
Missouri Basin					
Big Blue: Blue Rapids, Kans.	*Feet* 20	15	15	*Feet* 24.0	15
Grand:					
Chillicothe, Mo.	18	16	17	19.6	16
Brunswick, Mo.	12	16	19	13.4	17
Gasconade: Jerome, Mo.	15	18	18	15.2	18
Missouri:					
Geddes, S. Dak.	12	1	2	12.2	2
Blair, Nebr.	18	3	6	19.4	4–5
Omaha, Nebr.	19	5	7	19.4	5
Nebraska City, Nebr.	15	3	8	17.1	6
Hermann, Mo.	21	17	19	22.6	18
St. Charles, Mo.	25	17	21	27.7	19
Ohio Basin					
Middle Fork of Tygart: Midvale, W. Va.	11	16	16	13.9	16
Buckhannon: Hall, W. Va.	10	16	18	12.9	16
Tygart:					
Belington, W. Va.	14	16	17	16.4	17
Dailey, W. Va.	9	16	17	12.4	16
Philippi, W. Va.	20	16	17	23.6	16
West Fork:					
Weston, W. Va.	15	16	17	20.2	16
Clarksburg, W. Va.	5	16	17	8.2	17
Monongahela:					
Lock No. 7, Greensboro, Pa.	30	16	17	35.0	17
Lock No. 4, near Charleroi, Pa.	30	17	17	32.6	16
Little Kanawha:					
Glenville, W. Va.	23	16	17	33.0	16
Creston, W. Va.	20	16	18	33.2	17
Hocking: Athens, Ohio	17	16	19	19.0	17
Elk: Clay, W. Va.	18	16	17	23.5	16
Scioto: Chillicothe, Ohio	16	17	18	17.3	18
Little Miami: Kings Mills, Ohio	17	15	16	18.3	16
Licking: Falmouth, Ky.	28	16	18	29.7	17
Green:					
Lock No. 6, Brownsville, Ky.	28	18	19	28.3	18
Lock No. 4, Woodbury	33	Mar. 31	2	34.6	2
		Apr. 18	20	34.2	19
Lock No. 2, Rumsey, Ky.	34	6	8	34.1	7
		18	30	37.7	23
West Fork White:					
Anderson, Ind.	10	16	18	14.0	16
Noblesville, Ind.	12	17	19	13.9	17
Elliston, Ind.	18	16	25	27.8	20
Edwardsport, Ind.	12	16	May 1	19.6	21
East Fork White:					
Seymour, Ind.	14	16	Apr. 20	17.7	17
Williams, Ind.	10	18	24	18.4	20
Shoals, Ind.	25	20	24	29.7	21
White:					
Petersburg, Ind.	16	17	29	24.8	23
Hazleton, Ind.	16	17	May 1	27.0	23
Wabash:					
Bluffton, Ind.	10	18	Apr. 18	10.0	18
Wabash, Ind.	12	16	20	17.7	17
Lafayette, Ind.	11	16	25	21.2	17
Covington, Ind.	16	16	26	25.5	19
Terre Haute, Ind.	14	16	28	22.0	20–21
Vincennes, Ind.	14	17	May 1	22.3	24
Mount Carmel, Ill.	17	17	2	25.2	24
New Harmony, Ind.	15	19	3	21.0	25
Ohio:					
Point Pleasant, W. Va.	40	17	Apr. 20	43.8	19
Dam No. 28, Huntington, W. Va.	50	17	19	50.6	18
Dam No. 29, Ashland, Ky.	51	17	20	54.6	18
Dam No. 30, Greenup, Ky.	52	17	21	56.0	18
Portsmouth, Ohio	50	17	21	55.2	19
Dam No. 32, Vanceburg, Ky.	53	17	21	56.0	19
Dam No. 33, Maysville, Ky.	50	17	22	55.9	19
Dam No. 35, Oneonta, Ky.	48	17	22	54.0	19
Dam No. 36, Brent, Ky.	52	17	22	57.9	19
Cincinnati, Ohio	52	17	23	58.1	19
Dam No. 37, Fernbank, Ohio	50	17	23	57.3	19
Dam No. 38, Grant, Ky.	51	17	23	56.7	20
Dam No. 39, Florence, Ind.	48	17	22	51.0	20
Louisville, Ky.:					
Upper gage	28	18	24	33.6	20–21
Lower gage	55	18	24	60.6	20–21
Dam No. 43, Evans Landing, Ind.	57	18	24	61.8	21
Dam No. 44, Leavenworth, Ind.	53	18	25	61.2	21
Dam No. 45, Addison, Ky.	47	18	26	53.0	22
Tell City, Ind.	38	17	27	45.1	22
Dam No. 46, Owensboro, Ky.	41	19	26	44.0	22
Dam No. 47, Newburgh, Ind.	38	17	29	45.8	23
Evansville, Ind.	35	17	30	43.4	23
Dam No. 48, Cypress, Ind.	38	18	30	45.7	24
Mt. Vernon, Ind.	35	18	May 1	44.2	25
Dam No. 49, Uniontown, Ky.	37	19	2	47.2	26

Table of flood stages during April and May 1939—Continued

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI SYSTEM—continued					
Ohio Basin—Continued	Feet			Feet	
Ohio—Continued.					
Shawneetown, Ill	33	9	Apr. 12	33.7	10
		17	May 3	48.0	27
Dam No. 50, Fords Ferry, Ky	34	8	Apr. 13	35.6	10
		17	May 4	50.5	27
Dam No. 51, Golconda, Ill	40	21	2	46.3	27–28
Dam No. 52, Brookport, Ill	37	18	4	45.1	28
Dam No. 53, Grand Chain, Ill	42	[1] 6	5	51.0	26–27
Cairo, Ill	40	8	5	50.5	25–26
White Basin					
Black:					
Leeper, Mo	11	17	Apr. 18	13.6	17
Williamsville, Mo	11	16	19	15.6	18
Poplar Bluff, Mo	14	17	20	17.4	19
Black Rock Ark	14	6	12	15.4	8
		16	May 6	24.8	18
White:					
Calico Rock, Ark	18	17	Apr. 19	30.5	17
		May 27	May 28	24.7	May 27
Batesville, Ark	23	Apr. 17	Apr. 21	33.3	Apr. 18
		May 14	May 16	24.1	May 15
		28	29	28.6	28
Newport, Ark	26	Apr. 18	Apr. 25	30.3	Apr. 20
Georgetown, Ark	21	May 17	May 9	27.0	24
		19	[1]	22.8	May 31
Clarendon, Ark	26	Feb. 5	Apr. 3	29.8	Mar. 6–7
					15–17
		Apr. 16	May 15	30.7	Apr. 28–30
		May 26	[1]	26.7	May 31
St. Charles, Ark	25	Feb. 8	Apr. 9	28.3	Mar. 7–8
		Apr. 17	May 18	29.0	May 2
Arkansas Basin					
North Canadian:					
Canton, Okla	9	6	Apr. 7	9.2	Apr. 6
		7	20	12.0	9
Yukon, Okla	8	May 10	May 11	8.4	May 10
Poteau: Poteau, Okla	21	Apr. 6	Apr. 8	26.8	Apr. 8
		16	21	35.2	18
Petit Jean: Danville, Ark	20	7	9	22.5	8
		16	21	31.8	17
Red Basin					
Saline: Benton, Ark	20	16	17	27.4	17
Little Missouri: Boughton, Ark	20	18	19	21.3	18
Ouachita:					
Arkadelphia, Ark	17	6	8	20.2	8
		17	20	28.2	17
Camden, Ark	26	Mar. 31	27	37.6	21
Black: Jonesville, La	50	26	May 2	51.1	6
Little: White Cliffs, Ark	25	Apr. 9	Apr. 11	25.8	9
		18	24	27.8	20

Table of flood stages during April and May 1939—Continued

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
Red Basin—Continued	Feet			Feet	
Sulphur:					
Ringo Crossing, Tex	20	Mar. 26	1	24.4	Mar. 27
		Apr. 6	10	25.2	Apr. 6
		17	21	27.5	17
Naples, Tex	22	Mar. 29	15	28.3	1
		Apr. 20	26	26.3	21
Lower Mississippi Basin					
Big Lake Outlet: Manila, Ark	10	Feb. 3	May 14	14.7	24
St. Francis:					
Fisk, Mo	20	Apr. 7	Apr. 10	23.1	9
		18	24	24.3	20
St. Francis, Ark	18	11	May 1	22.8	23
		17	Apr. 22	15.3	18
Coldwater: Coldwater, Miss.[3]	13	26	30	13.6	28
		May 22	May 27	13.6	May 24
Tallahatchie: Swan Lake, Miss	26	Feb. 4	16	[4] 31.7	Apr. 3
Yazoo:					
Greenwood, Miss	35	Apr. 7	Apr. 20	35.9	12–13
Yazoo City, Miss	29	Mar. 5	May 24	33.1	28
Mississippi:					
New Madrid, Mo	34	Apr. 18	5	39.2	26
					30
Memphis, Tenn	34	24	7	37.0	May 1–2
Helena, Ark	44	Feb. 20	Apr. 2	48.2	Mar. 25–27
		Apr. 26	May 10	47.5	May 3–4
Greenville, Miss	36	Feb. 28	Apr. 4	38.5	Mar. 30
		Apr. 27	May 12	38.5	May 5–7
Natchez, Miss	48	Mar. 26	Apr. 6	49.2	Mar. 31
					Apr. 1
Angola, La	45	5	13	48.1	1–3
		Apr. 30	May 17	46.9	May 10–12
Baton Rouge, La	35	Mar. 3	Apr. 14	38.5	Apr. 2–4
		Apr. 28	May 18	37.2	May 11–12
Donaldsonville, La	28	Mar. 6	Apr. 12	30.2	Apr. 3
		May 4	May 16	29.0	May 10–12
Reserve, La	22	Mar. 12	Apr. 9	23.1	Apr. 2–4
		May 7	May 14	22.3	May 12–13
New Orleans, La	17	Mar. 29	Apr. 8	17.5	Apr. 2
Atchafalaya:					
Simmsport, La	41	28	11	42.1	5–6
Melville, La	37	Mar. 7	15	39.1	4–7
		May 2	May 17	37.9	May 12–13
Atchafalaya, La	25	Mar. 21	Apr. 14	25.3	Apr. 2–7
		May 7	May 15	25.1	May 9–14
		Apr. 5	Apr. 6	6.8	Apr. 6
Morgan City, La	6	May 8	May 8	6.0	May 8
		20	20	6.0	20
West Gulf of Mexico Drainage					
Elm Fork: Carrollton, Tex	7	Apr. 17	Apr. 18	7.5	Apr. 17
Trinity: Dallas, Tex	28	18	19	29.7	18
Nueces: Cotulla, Tex	15	May 8	May 8	15.3	May 8
		16	17	16.7	16
Rio Grande: Brownsville, Tex	18	16	16	18.2	16

[1] Continued into June.
[2] Went slightly below flood stage Apr. 14.
[3] Station established Apr. 16, 1939.
[4] Crest of 33.0 occurred on Feb. 22–23.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, W. E. HURD, acting in charge]

NORTH ATLANTIC OCEAN, MAY 1939

By H. C. HUNTER

Atmospheric pressure.—The eastern North Atlantic had pressure higher than the normal of the month, notably the area near the British Isles, where the station at Lerwick, Shetland Islands, averaged 0.29 inch above. From the 35th parallel of latitude southward practically all portions averaged close to or a trifle above normal. Over middle, but especially higher, latitudes, from the 30th meridian westward the pressure was lower than normal, on the average, but the fluctuations here were marked and came in quick succession; the first 10 days and the final fortnight had mostly lower pressure than the week from the 11th to 17th.

The extremes of pressure found in vessel reports at hand were 30.61 and 28.72 inches. The higher mark was reported by the American steamship *Memphis City*, on the forenoon of the 25th, when about 170 miles west of Valencia, Ireland. The lower reading was noted by the Danish steamship *Kentucky*, close to 50° N., 35½° W., on the evening of the 9th.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, May 1939*

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.71	−0.14	30.18	13	29.30	23
Reykjavik, Iceland	29.94	+.02	30.39	28	29.00	23
Lerwick, Shetland Islands	30.09	+.29	30.48	28	29.59	5
Valencia, Ireland	30.12	+.17	30.59	25	29.29	5
Lisbon, Portugal	30.04	+.07	30.30	8	29.68	2
Madeira	[1] 30.05	+.04	30.27	4	29.80	2
Horta, Azores	30.16	.00	30.44	24	29.82	14
Belle Isle, Newfoundland	29.86	−.03	30.42	16	29.00	31
Halifax, Nova Scotia	29.96	−.01	30.34	26	29.46	10
Nantucket	29.96	−.03	30.31	13	29.47	9
Hatteras	30.02	+.01	30.31	19	29.68	9
Bermuda	30.11	.00	30.28	19	29.90	15
Turks Island	30.00	.00	30.08	27	29.95	3
Key West	29.97	.00	30.11	5	29.88	8
New Orleans	29.96	−.01	30.14	4	29.74	8

[1] For 23 days.

NOTE.—All data based on a. m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—More encounters with gales than usually occur during May have been reported, the first 9 days being particularly stormy for the season.

A LOW of large area was centered near southern Greenland on the 2d and 3d, and thence it advanced toward the east-southeast, with some increase in energy, by the 4th, when it was central about 400 miles west-northwest of Ireland. The eastern portions of the chief steamship routes to northwestern Europe were considerably affected for 2 or 3 days, but the cyclone lost strength by the 6th, when it had advanced but a moderate distance farther; thereafter it consolidated with a LOW which had come from the American side of the ocean.

This latter LOW, which was little developed when near Georgia on the 1st, had gained decidedly in energy by the morning of the 3d, when the center was east of the Virginia capes. All three of the month's reports so far received of wind forces greater than 10 were connected with this storm, on the 3d; these intense winds were met not far from the southeastern coast of New Jersey, and the directions were between north-northwest and northeast. The American tank steamship *Cities Service Koolmotor* had a force of 12, while the battleship *Tennessee* and the liner *Barbara* estimated the highest force as 11.

Continued advance toward the northeast brought the LOW to the southern Grand Banks by the 6th, and to a position near 47° N., 34° W., by the forenoon of the 8th. Consolidation with the preceding LOW had now occurred, and a very energetic cyclone resulted. But after 2 days with little movement the center lost force rapidly and drew northward toward Greenland. Thereafter for about a week the much-traveled portions of the North Atlantic were practically free from winds of forces greater than 7.

The most notable gales of the second half of May were connected with a LOW system which, early on the 18th, extended from north to south near the 60th meridian, with deepest center over the Gulf of St. Lawrence. Consolidation of the centers followed, so that during the 19th and 20th there was one intense center located a short distance to northeastward of Labrador. By the 21st the center was near Cape Farewell, but from it a rather narrow trough extended far to the southward. Strong winds were met by several vessels within the area affected, and one, the Coast Guard cutter *Chelan*, patrolling to southeastward of Cape Race, recorded force 10.

By the 23d the LOW center was close to western Iceland, and was ceasing to have marked effects on the weather along the main traveled lanes.

Fog.—The amount of fog increased over that of the month before, as generally happens during spring. Compared with April 1939, more foggy days were noted almost everywhere to northward of the 35th parallel, especially from the coasts of New England to the southern Grand Banks and from the 25th meridian to the vicinity of the British Isles.

When the records of previous Mays are scanned, the present May is indicated as substantially normal for fogginess over western areas to northward of 35° N., but it was foggier than the average around the western Azores and for approximately 500 miles to westward of them, also near the British Isles and the Bay of Biscay and for about 700 miles to westward.

The 5°-square of the whole North Atlantic with most reported fog was that located near the southern edge of the Grand Banks, 40° to 45° N., 45° to 50° W., where 17 days brought fog. For the Grand Banks and vicinity the least foggy portions of the month were the first 8 days and the period from the 19th to the end. Close to the northeastern coast of the United States, however, fog was rather infrequent until the 21st, but quite common thereafter.

Over the eastern half of the North Atlantic reports indicate the most foggy square was that from 45° to 50° N., 10° to 15° W., with 8 days. The period from the 7th to the 15th was the time when fog occurred most often over these eastern areas.

OCEAN GALES AND STORMS, MAY 1939

Vessel	Voyage		Position at time of lowest barometer		Gale began May	Time of lowest barometer, May	Gale ended May	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Heddernheim, Ger. S. S.	Iggesund	Portland, Maine.	52 18 N.	35 42 W.	1	4a, 2	2	29.43	SE	SSW, 8	W	W, 9	SSW-W.
Amapala, Hond. S. S.	Celba	New York	31 36 N.	78 36 W.	3	7p, 2	3	29.91		N, 6		NW, 8	W-N-NNW.
Heddernheim, Ger. S. S.	Iggesund	Portland, Maine.	52 00 N.	36 00 W.	3	3a, 3	5	29.36	SSE	SW, 8	NW	W, 10	SSE-SW-NW.
Cities Service Kool-motor, Am. S. S.	Texas City	Boston	37 30 N.	72 00 W.	2	4a, 3	3	29.32	NE	NE, 12	E	NE, 12	NE-E.
Gulfwing, Am. M. S.	Las Piedras	New York	38 10 N.	73 38 W.	2	4a, 3	3	29.69	NE	NE, 9	NE	NE, 9	None.
Barbara, Am. S. S.	San Juan	Philadelphia	35 12 N.	73 30 W.	3	6a, 3	4	29.74	NNW	NW, 6	NW	NNW, 11	WNW-NNW.
Knoxville City, Am. S. S.	Avonmouth	Portland, Maine.	46 21 N.	31 36 W.	1	Noon, 3	4	[1]29.66	S	SW, 7	WNW	WNW, 9	SSW-WNW.
Mormacsea, Am. S. S.	Copenhagen	New York	51 30 N.	33 10 W.	3	4p, 3	4	29.23	WSW	WSW, 9	NW	NW, 10	WSW-NW.
Tennessee, U. S. N.	New York	Cristobal	38 46 N.	73 45 W.	3	4p, 3	4	29.74	NE	N, 11	WNW	N, 11	NE-N.
San Jose, Am. S. S.	Boston	Cortes	37 38 N.	71 57 W.	3	6p, 3	4	29.36	E	SSE, 7	SW	NNW, 8	SSE-Var-NW.
Nankai Maru, Jap. M. S.	Hamburg	New York	47 34 N.	26 07 W.	3	8p, 3	5	29.59	WSW	WSW, 7	NW	WNW, 8	SW-W.
Svanhild, Dan. S. S.	Aalborg	do	40 30 N.	71 30 W.	3	7a, 4	4	29.68	NE	NW, 8	NW	NW, 8	
Javanese Prince, Br. M. S.	Dakar	Halifax	[2]44 12 N.	63 02 W.	4	2a, 5	4	29.45		E, 6		ESE, 8	ENE-E.
West Cohas, Am. S. S.	New Orleans	Liverpool	50 14 N	17 23 W.	3	Noon, 5	5	29.30	SW	W, 5	W	W, 8	W-WSW.
Jean Lafitte, Am. S. S.	Mobile	do	49 10 N.	21 25 W.	3	2p, 5	5	29.26	WSW	NW, 8	NW	NW, 8	WNW-NW.
Pres. Garfield, Am. S. S.	Gibraltar	New York	41 20 N.	55 00 W.	5	4p, 5	6	29.60	WSW	SW, 8	NW	WNW, 8	SSW-WSW.
Duchess of Atholl, Br. S. S.	Quebec	Liverpool	53 00 N.	22 48 W.	4	5p, 5	5	29.05	W	WNW, 6	WNW	WNW, 8	WNW-NW.
Cheyenne, Br. M. S.	Baytown	Gothenburg	[2]53 58 N.	22 49 W.	3	8p, 5	4	[1]29.22	WSW	WNW, 4	W	NW, 10	WNW-SW.
Collamer, Am. S. S.	Havre	New York	41 03 N.	53 20 W.	5	8a, 6	6	29.58	W	W, 9	NW	W, 9	W-NW.
R. G. Stewart, Am. S. S.	Las Piedras	Southampton	35 58 N.	46 34 W.	8	8a, 8	9	29.52	NW	SW, 6	NW	NNW, 8	SSW-NW.
Montreal City, Br. S. S.	Fowey	Portland, Maine.	48 36 N.	29 52 W.	8	Noon, 8	8	29.39	SW	SW, 8	SW	SW, 8	SSE-SW.
Lucia C, Ital. S. S.	Gibraltar	New York	35 12 N.	43 00 W.	7	1p, 8	9	29.64	SW	SW, 7	NW	SW, 8	SW-NW.
Scanpenn, Am. S. S.	Copenhagen	do	55 30 N.	25 25 W.	9	1a, 9	9	29.32	SW	SW, 7	SW	SW, 9	S-SW.
Montreal City, Br. S. S.	Fowey	Portland, Maine.	48 10 N.	34 04 W.	9	Noon, 9	9	28.92	SSE	SSE, 8	WSW	WSW, 10	SSE-WSW.
Kentucky, Dan. S. S.	Aalborg	Norfolk	50 13 N.	35 31 W.	9	7p, 9	9	28.72	S	WSW, 10	SW	WSW, 10	S-WSW.
West Cobalt, Am. S. S.	New Orleans	Liverpool	[2]37 16 N.	67 37 W.	17	4a, 17	17	29.61	S	S, 6	SSW	SSW, 8	E-S.
Exmouth, Am. S. S.	Gibraltar	New York	40 14 N.	65 00 W.	17	8p, 17	18	29.67	S	S, 9	S	S, 9	None.
Chelan, U. S. C. G.	On ice patrol out from.	Halifax	43 45 N.	48 26 W.	20	8a, 21	20	29.84	S	SW, 4	SW	S, 10	
Arundo, Du. S. S.	Rotterdam	Habana	49 18 N.	45 54 W.	20	Noon, 21	21	[1]29.29		NW, 4		SW, 8	
American Shipper, Am. S. S.	Belfast	Boston	53 12 N.	19 18 W.	22	11a, 22	22	29.60		SSW, 8		SSW, 8	SSW-W.
Chelan, U. S. C. G.	On ice patrol out from.	Halifax	40 48 N.	49 06 W.	23	3p, 23	23	30.09	E	SW, 6	E	E, 9	E-SW.
Boston City, Br. S. S.	Montreal	Cardiff	48 36 N.	32 10 W.	24	10p, 24	25	30.07	S	S, 9	SW	SSW, 9	S-SW.
Chelan, U. S. C. G.	On ice patrol out from.	Halifax	40 20 N.	50 53 W.	24	6a, 25	25	30.05	SW	SW, 9	WSW	SW, 9	SW-WSW.
Rotterdam, Du. S. S.	Rotterdam	New York	[2]41 06 N.	62 06 W.	28	10p, 28	28	29.76	SW	WSW, 8	WSW	SW, 8	SW-WSW.
Henri Jaspar, Belg. S. S.	Southampton	do	40 39 N.	52 20 W.	28	2a, 29	29	29.75	S	W, 8	W	SW, 9	
Sarcoxie, Am. S. S.	Bremen	Boston	41 00 N.	54 30 W.	28	2a, 29	29	29.77	S	SW, 7	WSW	SW, 8	SSW-WSW.
Excello, Am. S. S.	Gibraltar	New York	39 54 N.	44 42 W.	29	6p, 29	29	29.84	SW	SW, 8	SSW	SW, 8	SW-SSW.
Do	do	do	39 24 N.	51 24 W.	31	6p, 31	31	29.81	SW	SW, 8	WSW	SW, 8	SW-NNW.
NORTH PACIFIC OCEAN													
City of Dalhart, Am. M. S.	Hong Kong	Los Angeles	39 48 N.	177 01 E.	2	2a, 3	3	29.66	NNE	NNE, 8	N	N, 9	NW-NNE.
Lacklan, Br. S. S.	Tarakan, Borneo.	Nagasaki	12 38 N.	124 14 E.	2	4a, 3	3	29.76	N	N, 3	SE	ENE, 7	N-NE.
Toorak, Br. S. S.	Hondagua	Los Angeles	37 13 N.	175 40 E.	2	8a, 3	4	29.84	N	NNW, 8	N	NNW, 8	None.
La Placentia, Am. S. S.	Port San Luis, Calif.	Vancouver, B. C.	41 56 N.	124 24 W.	4	2p, 5	5	29.93	NW	NNW, 8	N	NW, 8	None.
Ferncastle, Nor. M. S.	Shanghai	Los Angeles	43 29 N.	169 45 E.	7	2p, 8	9	29.61	E	ESE, 8	ESE	E, 9	E-ESE.
San Clemente Maru, Jap. M. S.	Los Angeles	Moji	32 40 N.	138 30 E.	8	10p, 8	9	29.06	ESE	S, 9	NNW	N, 10	SE-S-N.
Lacklan, Br. S. S.	Tarakan, Borneo.	Nagasaki	30 56 N.	135 45 E.	8	3p, 8	8	29.12	SE	N, 11	N	N, 12	S-N-NNE.
Silverpalm, Br. M. S.	Bugo, P. I.	Los Angeles	30 36 N.	170 22 W.	9	9p, 9	10	29.41	W	W, 8	NW	NNW, 8	W-NE.
Toa Maru, Jap. M. S.	Los Angeles	Tokuyama	46 15 N.	152 30 W.	12	7p, 12	12	29.27	S	SW, 7	W	SSW, 8	S-WNW.
Ixion, Br. S. S.	Yokohama	Victoria, B. C.	49 50 N.	151 55 W.	11	2a, 12	13	28.96	NNE	NE, 7	SSW	S, 9	NNE-S.
Evita, Nor. M. S.	Manila	Los Angeles	[2]35 30 N.	143 50 E.	19	6p, 21	22	29.30	E	NNW, 9	NW	NNW, 9	NW-NNW.
Bengkalis, Du. S. S.	do	San Francisco	33 50 N.	144 41 E.	21	8p, 21	23	29.44	WNW	WSW, 5	WNW	WNW, 8	WSW-WNW.

[1] Barometer uncorrected.

[2] Position approximate.

NORTH PACIFIC OCEAN, MAY 1939

By WILLIS E. HURD

Atmospheric pressure.—Although a considerable number of low-pressure areas crossed northern waters of the North Pacific during May 1939, they were not sufficiently deep to cause an average Aleutian LOW of much intensity. The lowest average pressure at a coastal land station in this region was 29.83 inches at Kodiak, which was 0.01 inch below the normal of the month. At St. Paul, in the Bering Sea, the average pressure, 29.96, was 0.12 inch above the normal, and readings at Dutch Harbor and Petropavlosk were above by nearly the same amount. Elsewhere, changes from the normal of May were small.

There were a number of days with pressure above 30 inches over the Aleutian region during the early half of the month. On the average for May, however, high pressure lay over that part of the ocean between about 35° and 50° N. along the American coast, and from there southwestward to beyond Midway Island.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, May 1939, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	29.99	−0.10	30.22	12	29.54	5
Dutch Harbor	29.94	+.10	30.44	8	29.36	17
St. Paul	29.96	+.12	30.40	8	29.30	17
Kodiak	29.83	−.01	30.30	1	29.54	27
Juneau	29.93	−.06	30.33	10	29.12	28
Tatoosh Island	30.07	+.06	30.32	7	29.73	28
San Francisco	30.00	+.01	30.23	19	29.78	29
Mazatlan	29.85	.00	29.90	16, 20, 21	29.80	4, 8, 24, 29, 31
Honolulu	30.04	−.01	30.15	13	29.88	9
Midway Island	30.09	+.04	30.27	5	29.86	10
Guam	29.86	−.02	29.92	1, 4, 5	29.77	24
Manila	29.78	+.01	29.86	13	29.65	4
Hong Kong	29.75	−.03	29.86	2, 15	29.56	29
Naha	29.85	+.03	30.00	14, 15, 26	29.65	7
Titijima	29.90	−.01	30.09	26	29.65	16, 20
Petropavlosk	29.94	+.11	30.48	9	29.41	14

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Cyclones and gales of the extratropics.—Despite the number of extratropical cyclones that crossed North Pacific waters during May 1939, none exhibited any great intensity, and the highest winds in the few gales reported for the month were not in excess of force 9. In addition to a number of cyclones that originated in high latitudes and remained in northern waters through most of their existence, there were several this month that had their origin in Japanese waters and close to the northward of Midway Island. Disturbances having the more southerly origin were those in which, as a rule, the stronger winds occurred.

As an instance of this peculiarity, may be mentioned the cyclone of May 1 to 4, which on the lst was central a little northwest of Midway Island and, after pursuing a northeasterly course, arrived in the Gulf of Alaska. The only gales reported in connection with it were of force 8 to 9, on the 2d and 3d, both experienced within the 5° region 35° to 40° N., 180° to 175° E.

On the 9th a further cyclone appeared near Midway Island. Late on that date the British motorship *Silverpalm* ran into a west gale of force 8, barometer 29.41, near 31° N., 170° W., and thereafter continued to experience moderate to fresh gales until the early morning of the 10th. The disturbance took an easterly then a north-northeasterly course and arrived in the Gulf of Alaska on the 13th. During the 11th to 13th gales of force 8 to 9 occurred within the 5° square 45° to 50° N., 150° to 155° W. Early on the 12th the British steamship *Ixion*, near 50° N., 152° W., reported the lowest barometer reading of the month, 28.96 inches, with an accompanying northeast wind of force 7. This was closely followed on ship by a wind of force 9 from the south.

On the 19th a disturbance lay south of central Japan. It took an irregular but generally northward course until the 23d, on which date the center lay east of the Kuril Islands. Thereafter its course was generally easterly to northeasterly until the 28th, when it lay off the coast of extreme southeastern Alaska. The only gales reported as accompanying this disturbance occurred on the 19th to 23d. The storm had its greatest apparent intensity during the night of the 21st-22d, when the Norwegian motorship *Evita* encountered north-northwesterly gales of force 9, lowest barometer 29.30, in the vicinity of 36° N., 144° E.

The only gale reported in the United States coastal waters was experienced by the American steamship *La Placentia* on the 5th, in latitude 41°56′ N., longitude 124°24′ W. A strong oceanic anticyclone was pressing at the time close upon the California coast.

Typhoon.—Subjoined is an account by the Reverend Bernard F. Doucette, S. J., Weather Bureau, Manila, P. I., of the typhoon of April 29 to May 9, 1939, in waters of the Far East. Mail reports from ships caught in this typhoon indicate its greatest intensity to have occurred on the 8th. The British steamship *Lacklan*, noted by Father Doucette as having a south wind of force 9, in 31° N., 136° E., at 1 p. m. of that date, ran into the full force of the storm shortly after 3. p. m. with a north gale of hurricane intensity. The lowest known barometer in connection with the typhoon was 29.06, read on board the Japanese motorship *San Clemente Maru* at 10 p. m. of the 8th, in 32°40′ N., 138°30′ E. It was accompanied by a south gale of force 9, and was followed at 10:20 p. m. by the highest wind at ship, a north gale of force 10.

Fog.—There was but little change in the amount of fog formation along the United States coast since April, but in northwestern Pacific waters, there was a considerable increase, as is usual in May. Within the area 41° to 46° N., 150° to 170° E., fog was reported on 11 days, with 4 to 5 days with fog in each of the included 5° squares. To the southeastward, between 30° and 35° N., 170° and 175° E., there were 3 days with fog. Scattered occurrences were reported to the eastward of mid-ocean, but on not more than 2 days in even the most frequented 5° square. Along the American coast ships reported 2 days with fog off Washington, 3 days with fog off Oregon, and 9 days with fog off California.

TYPHOONS AND DEPRESSIONS OVER THE FAR EAST

BERNARD F. DOUCETTE, S. J.

[Weather Bureau, Manila, P. I.]

Typhoon, April 29–May 9, 1939.—A low-pressure area appeared central about 300 miles south of Yap on the morning of April 29. It moved west-northwest, then north and north-northwest to the regions close to latitude 9°30′ N., longitude 130° E., where, during the morning hours of May 2, it intensified to depression strength. Moving in a west-northwesterly direction, it reached southern Samar during the afternoon hours of May 3 and continued during the evening and the next day toward Masbate. After it passed Masbate Island, if shifted its course to the north-northeast, then north, thus passing over the Camarines Provinces to the ocean regions east of central Luzon. Its movement on May 5 and 6, in a northerly direction, brought the center to the Balintang Channel. The shifting of the winds at Basco showed that the center moved north-northwest, reaching a position about 60 miles west of Basco, from which location it moved in an east-northeasterly direction, changing to the north when about 100 miles northeast of Basco (May 7, early morning hours). The center then moved to a position about 150 miles east of southern Formosa, where it changed to the northeast, intensifying to typhoon strength and moving more rapidly. On May 9, the center was located close to the coast line of central Japan, perhaps about 100 miles southeast of Tokyo. The afternoon hours showed the storm weakening as it moved along a northeasterly course away from Japan.

From May 2 to 6, a typhoon situation prevailed over the Philippines. On May 3 to 5, when the center was over the Visayan Islands, the lowest pressures reported

varied between 751 and 752 mm. (29.567 and 29.606 inches), with winds from force 1 to 3. The strongest winds reported were at a distance from the center, and very likely due to local effects. Legaspi and Sorsogon had northeast winds, force 5 and 6, when the center was near Samar Island. Cebu and Tacloban reported south-quadrant winds, force 5 and 6, when the center was approaching or passing over the Camarines Provinces. As the center moved northward, close to the eastern coast of Luzon and approached the Balintang Channel, pressure values reported from Vigan and Laoag seemed to indicate that the center was about to move northwest or even west into the China Sea. The high pressure values at the Loochoo (Nansei) Island stations helped in giving the impression that the storm would take such a course, but on the afternoon of May 6, these stations reported lower pressure values as the HIGH over the ocean began to move eastward. This change in the situation allowed the storm center to take its northeasterly course.

Manila newspapers printed a dispatch, dated May 6, from Basco, Batanes Islands, that 90 fishermen were caught by the strong winds over the regions east of those islands. One man was drowned and eleven missing. The U. S. S. *Trinity* was traveling southward and reported from latitude 20.3° N., longitude 124.1° east, winds of force 9, squally weather, and pressure of 753.1 mm. (29.650 inches), May 6, 6 p. m. This was at the period when the center was over the eastern part of the Balintang Channel and shifting to the north-northwest.

From May 7 to 9, as the storm moved from the Bashi Channel and locality to Japan, it manifested its power on the surface much more than when it was over the Philippine Archipelago. Oshima, May 8, 5 a. m. (Manila time), had north-northeast winds and 749.5 mm. (29.508 inches) as pressure; Borodino reported west-southwest winds, force 5, and pressure of 749.2 mm. (29.496 inches), while Naha had north winds, force 5, with pressure at 753.0 mm. (29.646 inches). On May 8, 1 p. m., the S. S. *Lacklan* reported from latitude 31.0 N., longitude 136.0 E., a value of 739.5 mm. (29.114 inches) for pressure, with winds of force 9 from the south.

During the last 10 days of April, there was a weak east-quadrant air stream north of the Equator and another mild current from the west quadrant south of the Equator, the front separating these air currents extending east to west, parallel to and a short distance north of the Equator. All of the available pilots from the Netherlands East Indies showed that this weak westerly current was not extensive, for Koepang, Timor Island, reported easterly winds during this period. On April 29 the velocities of the upper winds over Guam increased to values as high as 50 k. p. h. and then decreased during the next few days. This impulse reached Cebu, changing the direction from the southeast quadrant to the northeast, May 1 and 2, and increasing the velocities to values as high as 50 and 60 k. p. h. From April 30 to May 2 northeasterly winds appeared over Manila, the velocities increasing just when those at Cebu were decreasing. At the same time, Palau had a cloud movement from the south with rising pressure. As the center approached and crossed Samar into the Visayan Islands, May 2 to 6, the directions over Cebu, Zamboanga, Menado, and Tarakan shifted to the southwest quadrant. Of the pilots received from Menado, the highest velocities occurred on the afternoon of May 3, values of 50 k. p. h. being attained, while the other stations (except Makassar) of the Netherlands East Indies seldom had winds stronger than 20 k. p. h. (as far as can be ascertained from the available data). It seems that the velocities increased as though the action was caused by the storm center and not due to action far away from the disturbance. After the center had crossed the Camarines Provinces and was moving northward, only short ascents were possible at Manila due to low clouds and rain. Easterly winds at Manila did not reach values of 50 k. p. h. but the southwest quadrant winds, flowing toward the disturbance as it approached the Balintang Channel, reached values as high as 50 k. p. h. on a few ascents. At Aparri, however, the easterly winds, which attained velocities as high as 55 k. p. h., did not go above 45 k. p. h. after the directions shifted to the north and northwest and finally to the southwest quadrant. The upper winds indicated the existence of a definite, but not violent, circulation as the disturbance moved over the Archipelago and adjacent regions.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

TABLE 1.—*Condensed climatological summary of temperature and precipitation by sections, May 1939*

[For description of tables and charts, see REVIEW, January, p. 31]

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	71.0	−0.3	2 stations	93	[1] 17	Valley Head	36	3	5.48	+1.36	Spring Hill	16.56	Primrose Farm	1.74
Arizona	67.6	+1.6	do	110	[1] 28	Pinedale	21	12	.04	−.28	Grand Canyon	.43	75 stations	.00
Arkansas	69.4	+.2	do	96	[1] 22	2 stations	34	3	4.85	−.13	Eureka Springs	11.17	Index	.35
California	61.7	+.3	Cow Creek	116	29	Tamarack	11	19	.97	+.03	Lake Spaulding	5.54	17 stations	.00
Colorado	55.9	+3.6	Las Animas	99	22	Dillon	11	7	1.03	−.86	Ordway	4.10	2 stations	T
Florida	74.9	−.7	4 stations	96	[1] 23	Vernon	40	3	5.02	+1.02	River Junction	12.20	Glen St. Mary	1.59
Georgia	70.4	−1.1	3 stations	96	[1] 24	Blairsville	27	3	4.12	+.66	Douglas	9.12	Midville	1.70
Idaho	56.1	+3.1	do	100	[1] 15	Big Creek	12	25	.81	−.83	Cottonwood	2.53	Mountain Home	T
Illinois	66.2	+3.4	10 stations	95	[1] 23	Morris	27	3	2.43	−1.61	Elgin	6.31	Shawneetown	.97
Indiana	65.2	+2.9	Madison	100	24	3 stations	28	[1] 1	1.56	−2.43	Gary	6.06	Bluffton	.47
Iowa	66.4	+6.3	Boone	105	24	Sibley	30	11	2.07	−1.99	Keokuk	5.80	Indianola	.47
Kansas	68.5	+4.6	2 stations	108	23	2 stations	32	[1] 13	2.35	−1.48	Oswego	10.19	McPherson	.20
Kentucky	66.3	+.9	Quicksand	93	24	Greensburg	30	5	1.37	−2.60	Lancaster	4.51	Covington	.55
Louisiana	73.3	−.4	2 stations	95	[1] 21	2 stations	40	[1] 3	6.72	+2.12	Port Sulphur	14.61	Plain Dealing	1.65
Maryland-Delaware	65.0	+2.6	Cumberland, Md	98	31	Oakland, Md	25	4	1.08	−2.38	Sines, Md	3.05	Conowingo, Md	.17
Michigan	57.0	+3.5	Houghton Lake (near)	96	31	2 stations	16	12	2.38	−.81	Ironwood	5.60	Saginaw	.53
Minnesota	60.8	+5.5	Ada	107	30	do	20	[1] 11	2.30	−.91	Hinckley	6.21	Mahnomen	.28
Mississippi	71.5	−.3	Moorhead	96	22	4 stations	40	4	5.53	+1.17	Bay St. Louis	12.07	Clarksdale	1.55
Missouri	67.4	+2.9	Unionville	102	24	Doniphan	31	4	4.17	−.60	Dean	11.58	Kidder	.76
Montana	55.8	+3.8	3 stations	96	[1] 16	Conway's Ranch	15	12	1.89	−.22	Turner	4.37	Adel (near)	.48
Nebraska	65.9	+6.6	Agronomy Farm (Lincoln)	102	30	Harrison	23	8	2.53	−.91	Cairo	7.71	Potter	.26
Nevada	59.1	+3.5	Overton	111	29	Marlette Lake	20	19	.73	−.14	Yerington	2.38	Searchlight	.00
New England	55.2	+.1	4 stations	94	[1] 28	Plymouth, N. H	20	3	1.75	−1.57	Rochester, Vt	3.85	2 stations	.57
New Jersey	63.3	+2.9	2 stations	99	31	Charlotteburg	25	16	1.43	−2.30	Indian Mills	4.68	Long Branch	.21
New Mexico	60.8	+1.2	do	103	[1] 19	Gavilan	19	[1] 24	.72	−.46	Portales Evap. Station	3.03	15 stations	.00
New York	58.5	+2.5	Scarsdale	99	31	4 stations	21	[1] 3	1.68	−1.75	Hoffmeister	3.39	Mount Vernon	.50
North Carolina	66.4	−.4	Goldsboro	98	24	Mount Mitchell	20	3	2.89	−1.17	Highlands	7.08	Manteo	.36
North Dakota	60.1	+6.5	2 stations	104	[1] 29	McHenry	18	11	1.55	−.75	Dickinson	3.22	Fargo	.44
Ohio	63.7	+3.2	Gallipolis (near)	98	26	2 stations	26	[1] 2	1.25	−2.41	Portsmouth No. 1	3.30	Holgate	.21
Oklahoma	71.5	+3.1	Hollis	109	22	Hooker	34	9	3.76	−.95	Pensacola	9.66	Hooker	.76
Oregon	55.5	+2.3	Umatilla	100	14	Chemult	12	5	1.07	−.64	Cascadia	3.89	Arlington	.01
Pennsylvania	62.8	+3.2	Marcus Hook	99	30	Brookville	20	4	1.58	−2.25	Morris Run	3.66	2 stations	.21
South Carolina	69.8	−1.1	Lake City	99	24	Santuck	32	4	3.45	−.13	Caesars Head	8.27	Darlington	1.39
South Dakota	64.2	+7.8	Dupree	103	30	2 stations	25	11	2.32	−.55	Pukwana	5.79	Redig	.28
Tennessee	67.0	+.1	Celina	94	25	Erwin	28	4	3.37	−.80	Waynesboro	7.60	Rogersville	.76
Texas	75.2	+2.2	Quanah	108	22	Mount Locke	37	13	3.16	−.48	Carrizo Springs	9.09	El Paso	.01
Utah	58.1	+2.7	St. George	101	29	Clear Creek	19	23	.86	−.36	Logan	2.33	2 stations	T
Virginia	65.4	+1.3	2 stations	97	31	Burkes Garden	21	4	1.67	−2.02	Saltville	4.62	do	.41
Washington	56.4	+1.9	Kennewick	101	14	2 stations	21	[1] 1	1.52	−.42	Quinault	7.94	Kennewick	.01
West Virginia	63.5	+1.8	Martinsburg	100	31	Seneca State Forest	19	4	1.38	−2.57	Dailey	3.78	2 stations	.36
Wisconsin	59.6	+4.3	4 stations	97	[1] 30	Long Lake	17	[1] 1	2.74	−.84	Rest Lake	8.48	Darlington	.69
Wyoming	53.8	+4.3	Torrington	100	30	Hunter's Station	12	1	1.57	−.50	Quaking Aspen Creek	5.81	Rawlins	.12
Alaska (April)	30.3	+3.6	3 stations	59	[1] 8	Allakaket	−45	1	1.91	+.45	Viewcove	18.27	2 stations	.00
Hawaii	72.0	+.1	Hilo	91	11	Kanalohuluhulu	44	11	5.65	−.37	Kukui	56.00	Reservoir No. 8	.00
Puerto Rico	75.7	−.6	Juncos	97	24	Barranquitas	54	11	5.42	−2.40	La Mina (El Yunque)	18.51	Santa Rita	.00

[1] Other dates also.

TABLE 2.—*Climatological data for Weather Bureau stations, May 1939*

[Compiled by Annie E. Small by official authority U. S. Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. +mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	°*F.*		°*F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England							**55.3**	**+0.7**										**72**	**1.54**	**−1.6**										**5.5**		
Eastport	75	67	85	29.87	29.96	0.00	**48.0**	**+0.3**	75	28	56	32	2	40	31	43	39	**78**	**1.40**	**−1.6**	10	8.9	sw.	26	e.	4	7	11	13	6.0	0.0	0.0
Greenville, Maine	1,069	4	41																												
Portland, Maine	103	82	117	29.85	29.97	.00	53.2	−.1	86	28	62	36	3	45	32	46	40	66	1.52	−1.9	10	7.6	s.	26	nw.	18	14	6	11	4.8	T	.0
Concord	289	54	72	29.66	29.97	−.01	56.8	+2.5	86	28	70	29	16	44	43				1.98	−1.0	7	5.8	se.	19	w.	30	13	10	8	4.9	.0	.0
Burlington	403	11	48	29.50	29.94	−.03	54.8	−1.7	82	8	66	31	3	44	35	48	42	65	3.38	+.5	12	8.7	s.	29	s.	9	9	10	12	5.8	.0	.0
Northfield	876	12	60	29.02	29.97	.00	52.1	−.7	84	8	66	24	3	38	44	47	40	64	2.52	−.2	11	7.2	sw.	22	sw.	10	9	15	7	5.5	.0	.0
Boston [1]	29	33	62	29.92	29.95	−.03	56.4	−.7	90	28	65	39	1	48	32	50	44	69	1.29	−1.9	6	10.7	e.	28		29	5	14	12	6.6	.0	.0
Nantucket	12	14	90	29.94	29.96	−.03	52.4	+.1	80	31	59	39	2	45	28	49	46	85	1.36	−1.5	8	15.2	sw.	46	ne.	3	10	9	12	5.8	.0	.0
Block Island	26	11	46	29.93	29.96	−.03	53.7	+.9	82	31	61	40	14	46	32	50	47	84	.90	−2.6	9	14.2	sw.	43	ne.	3	13	9	9	4.5	.0	.0
Providence	159	215	251	29.79	29.96	−.02	58.8	+.3	90	28	69	36	1	48	39	52	47	69	.57	−2.4	6	10.4	nw.	33	nw.	29	11	12	8	5.1	.0	.0
Hartford	159	66	100	29.79	29.96	−.02	61.8	+4.3	92	31	73	34	14	51	35				.96	−2.6	6	8.2	s.	24	w.	28	4	15	12	6.2	.0	.0
New Haven	106	74	153	29.85	29.96	−.03	60.0	+2.1	89	7	69	37	14	51	35	53	46	64	1.04	−2.6	5	8.5	s.	30	n.	3	6	17	8	5.5	.0	.0
Middle Atlantic States							**64.8**	**+2.8**										**64**	**1.28**	**−2.2**										**5.2**		
Albany [1]	292	26	40	29.62	29.94	−.04	60.6	+1.3	86	7	73	33	1	48	50	52	44	58	1.11	−1.8	8	9.7	s.	31	nw.	10	6	13	12	6.3	.0	.0
Binghamton	871	57	79	29.04	29.97	−.01	61.2	+3.8	91	31	74	32	2	48	50	53	46	61	.82	−2.5	8	5.9	nw.	30	sw.	9	4	13	14	6.5	.0	.0
New York	314	415	454	29.62	29.95	−.04	63.7	+3.1	92	31	72	41	14	55	27	54	47	60	.56	−2.7	6	12.5	w.	35	w.	28	13	9	9	5.2	.0	.0
Harrisburg [1]	351	30	49	29.60	29.98	.00	66.4	+4.6	97	31	79	36	1	54	39	56	49	57	.54	−2.9	5	7.6	w.	26	sw.	27	10	13	8	5.1	.0	.0
Philadelphia	114	174	367	29.85	29.98	−.01	66.4	+3.5	94	31	76	42	1	57	31	56	50	60	1.91	−1.4	4	11.9	sw.	39	n.	3	13	10	8	4.6	.0	.0
Reading	323	283	306	29.62	29.97		65.9	+3.4	93	31	76	38	1	56	33	56	49	58	1.39	−2.3	3	10.6	nw.	29	w.	28	14	10	7	4.3	.0	.0
Scranton	805	72	104	29.10	29.96	−.02	62.8	+3.4	91	31	75	33	2	51	42	54	47	60	2.17	−1.1	7	6.4	sw.	23	nw.	21	10	14	7	4.6	.0	.0
Atlantic City	52	37	172	29.92	29.98	.00	60.8	+2.7	90	31	68	40	1	54	27	54	50	75	.89	−2.2	4	16.1	s.	50	n.	3	11	10	10	5.5	.0	.0
Sandy Hook	22	10	57	29.93	29.96		62.0	+3.6	91	31	70	44	14	54	29	54	49	69	1.34	−2.4	7	12.0	sw.	39	ne.	3	13	7	11	4.9	.0	.0
Trenton	190	89	107	29.76	29.96		64.4	+3.3	93	31	75	39	13	53	35	55	49	62	1.18	−1.9	8	8.4	s.	25	n.	3	9	12	10	5.7	.0	.0
Baltimore	123	100	215	29.85	29.98	−.01	68.4	+4.0	94	31	78	41	1	59	32	58	50	57	1.47	−2.1	4	10.0	sw.	30	sw.	22	12	11	8	4.7	.0	.0
Washington	112	62	85		29.98	−.02	68.0	+4.3	95	31	79	40	1	57	38	58	52	61	.41	−3.3	3	6.2	sw.	19	ne.	3	11	12	8	4.9	.0	.0
Cape Henry	18	8	54	29.98	30.00		66.0	+1.8	93	29	74	43	4	58	27	61	58	78	1.63	−1.9	8	12.2	sw.	37	nw.	3	13	7	11	5.1	.0	.0
Lynchburg	686	144	184	29.28	30.01	+.01	68.2	+.9	92	23	80	38	15	56	38	58	52	63	1.33	−2.3	6	6.8	sw.	34	nw.	11	10	13	8	5.2	.0	.0
Norfolk	91	80	125	29.92	30.02	+.02	67.8	+1.6	92	31	77	45	2	58	32	59	54	68	1.53	−2.3	6	10.0	sw.	27	nw.	11	10	8	13	5.7	.0	.0
Richmond	144	11	52	29.86	30.01	+.02	67.8	+1.3	93	31	79	42	1	56	39	59	54	68	1.80	−2.0	8	7.6	sw.	29	nw.	11	16	8	7	4.1	.0	.0
Wytheville	2,304	49	55	27.65	30.02	+.03	61.6	+.2	85	31	74	32	4	50	38	55	50	71	1.63	−2.0	9	5.4	w.	28	nw.	29	8	12	11	5.9	.0	.0
South Atlantic States							**69.9**	**−0.2**										**74**	**3.56**	**+0.1**										**5.4**		
Asheville	2,253	89	104	27.72	30.03	+.04	63.9	+1.3	90	24	76	34	4	52	39	60	52	73	2.78	−.6	14	6.8	nw.	25	nw.	13	6	9	16	6.4	.0	.0
Charlotte	779	63	86	29.19	30.02	+.03	69.1	+.2	95	24	80	43	15	59	31	60	55	66	3.60	.0	8	7.2	s.	25	sw.	9	7	13	11	6.2	.0	.0
Greensboro [1]	886	6	56	29.09	30.03		66.6		92	24	78	37	4	55	37	59	55	73	2.18		8	7.7	sw.	25	ne.	2	6	13	12	5.8	.0	.0
Hatteras	11	5	50	30.01	30.02	+.01	66.9	−1.8	82	24	72	48	2	62	18	63	60	82	2.95	−.8	5	13.5	sw.	50	n.	2	10	11	10	5.1	.0	.0
Raleigh	376	103	146	29.61	30.01	+.02	68.6	+.1	94	31	79	34	2	58	30	61	57	73	6.26	+2.4	11	8.3	sw.	34	w.	24	12	15	4	4.3	T	.0
Wilmington	72	73	107	29.96	30.03	+.02	69.4	−1.4	88	11	78	40	3	61	27	63	60	78	4.64	+1.2	8	9.2	sw.	31	nw.	2	11	10	10	4.8	.0	.0
Charleston	48	11	92	29.99	30.04	+.03	72.3	−.4	88	24	79	46	3	65	26	66	63	75	2.54	−.5	9	9.8	s.	23	n.	2	13	8	10	5.0	.0	.0
Columbia, S. C	347	70	91	29.65	30.02	+.02	71.0	−.9	92	24	82	41	3	60	32	62	58	70	3.47	+.4	10	7.9	s.	23	sw.	9	11	16	4	4.5	.0	.0
Greenville, S. C	1,040	70	78	28.92	30.01		67.8	+.6	92	24	78	42	3	57	33	60	55	68	3.82	−.2	9	6.3	sw.	29	sw.	25	7	10	14	6.2	.0	.0
Augusta	182	62	77	29.81	30.00	+.01	72.0	−.4	93	24	83	44	4	61	33	64	59	72	2.55	−.5	10	5.6	s.	25	nw.	13	9	12	10	5.7	.0	.0
Savannah	65	73	152	29.94	30.01	+.01	73.2	−.2	92	24	82	47	3	64	29	66	63	77	2.22	−.8	9	9.7	se.	31	w.	9	10	12	9	5.1	.0	.0
Jacksonville	43	86	110	29.98	30.02	+.02	75.2	+.2	91	28	84	55	4	67	23	67	64	75	4.34	+.3	8	7.5	se.	26	sw.	31	9	11	11	5.8	.0	.0
Florida Peninsula							**77.6**	**+0.4**										**76**	**6.06**	**+1.8**										**5.1**		
Key West	21	10	64	29.95	29.97	.00	79.5	+.4	89	9	85	68	4	74	17	72	70	74	2.71	−.8	12	9.6	e.	19	e.	6	8	13	10	5.6	.0	.0
Miami	25	124	168	29.98	30.00	+.01	77.4	+1.0	88	14	83	62	3	72	21	71	68	75	8.91	+2.7	10	10.1	se.	25	se.	30	8	14	9	5.5	.0	.0
Tampa	35	88	197	29.96	30.00	+.01	76.0	−.3	91	27	85	60	4	67	23	68	66	79	6.57	+3.6	11	10.2	e.	40	s.	25	14	12	5	4.2	.0	.0
East Gulf States							**71.9**	**−0.6**										**75**	**5.58**	**+1.7**										**6.4**		
Atlanta [1]	976	5	72	28.99	29.99	.00	69.3	−.6	92	25	80	41	4	58	36	61	57	74	3.82	+.4	14	7.4	se.	31	n.	13	5	6	20	7.0	.0	.0
Macon	370	79	87	29.62	30.01	+.02	70.8	−1.5	91	25	81	44	4	61	34	63	59	72	3.76	+.8	13	5.8	s.	30	nw.	10	4	12	15	6.7	.0	.0
Thomasville	273	49	58																												
Apalachicola	35	11	51	29.96	30.00		73.8	−.8	86	12	80	56	3	67	23	68	65	77	3.24	−.2	4	9.0	se.	24	se.	30	10	8	13	5.7	.0	.0
Pensacola	56	149	185	29.93	29.99	.00	73.0	−.9	82	2	78	55	3	68	21	68	65	78	7.23	+3.9	11	13.2	s.	36	s.	26	8	15	8	5.4	.0	.0
Anniston	741	9					68.5	+.1	87	28	79	40	4	58	36				4.06	+.1	16		s.				11	6	14		.0	.0
Birmingham	700	11	48	29.25	29.98	.00	69.9	−1.2	87	25	79	45	3	61	31	62	58	74	5.88	+1.9	16	6.5	s.	25	s.	27	5	12	14	6.5	.0	.0
Mobile	57	86	161	29.92	29.98	−.01	73.8	−.6	89	23	82	52	4	66	28	67	63	76	8.52	+4.2	13	10.1	se.	28	nw.	9	5	13	13	6.2	.0	.0
Montgomery	218	92	105	29.75	30.00	+.01	73.0	−.4	90	12	82	51	4	64	27	64	60	73	3.01	−.8	12	6.6	se.	20	se.	26	6	8	17	6.6	.0	.0
Meridian	375	67	92	29.57	29.96	−.02	71.9	+.6	92	12	82	44	4	62	35	64	60	74	5.23	+.9	13	5.4	s.	24	se.	25	6	9	16	6.2	.0	.0
Vicksburg	247	82	102	29.69	29.94	−.03	72.5	−.4	89	24	82	51	3	63	26	64	60	74	3.93	−.4	12	7.8	se.	31	nw.	22	6	7	18	6.7	.0	.0
New Orleans	53	76	84	29.91	29.96	−.01	74.9	−.5	88	22	82	60	9	68	22	67	64	76	12.72	+8.1	18	6.0	se.	18	ne.	19	7	7	17	6.5	.0	.0
West Gulf States							**75.1**	**+1.8**										**72**	**4.09**	**+0.1**										**5.1**		
Shreveport	249	92	227	29.67	29.98	−.02	74.7	+1.1	94	28	85	54	3	64	28	66	61	68	3.06	−1.2	9	9.4	s.	34	sw.	20	9	15	7	5.3	.0	.0
Bentonville	1,393	12	51	28.59	29.94	+.01	67.3	+.9	89	24	78	42	14	56	32				8.71	+3.5	14	5.8	s.	25	n.	22	16	4	11		.0	.0
Fort Smith	463	57	82	29.46	29.93	.00	71.1	+1.5	94	26	81	48	14	61	37	62	57	65	3.43	−1.4	9	7.4	e.	31	s.	25	11	13	7	4.8	.0	.0
Little Rock	357	94	102	29.56	29.93	−.02	69.8	−.5	88	24	79	51	14	61	32	62	58	72	6.95	+2.2	13	7.5	s.	41	n.	22	10	9	12	5.8	.0	.0
Austin	605	68	90	29.25	29.88		78.0	+3.4	99	21	89	59	1	67	32	67	63	66	3.01	−1.6	6	7.5	s.	31	nw.	13	10	13	8	5.1	.0	.0
Brownsville	57	88	96	29.80	29.86		79.2	+.6	94	27	86	66	1	72	20	73	71	83	6.20	+3.9	8	10.2	se.	31	n.	13	9	15	7	4.8	.0	.0
Corpus Christi	20	11	78	29.86	29.88	−.02	78.9	+2.7	89	19	85	67	31	73	19	73	71	82	2.22	−1.0	7	12.0	se.	38	ne.	18	8	13	10	5.5	.0	.0
Dallas	512	220	227	29.35	29.88		74.4		94	22	84	55	9	64	29	65	59	65	2.65	−1.8	5	11.1	se.	42	e.	16	13	12	6	4.8	.0	.0
Fort Worth	679	92	110	29.19	29.89	−.02	75.8	+3.5	98	22	86	54	9	65	31				2.54	−2.1	7	9.6	s.	41	s.	10	20	7	4	3.0	.0	.0
Galveston	54	106	114	29.86	29.92	−.02	76.6	+1.8	87	27	81	62	8	72	18	71	68	79	1.97	−1.4	7	10.3	s.	33	nw.	8	10	19	2	4.5	.0	.0
Houston	138	157	190	29.78	29.92		76.8	+1.3	92	27	86	58	5	67	31				3.12	−1.4	9	9.2	se.	43	nw.	8	6	18	7	5.8	.0	.0
Palestine	510	64	72		29.92	−.01	73.6	+.9	90	28	83	54	5	64				70	5.51	+1.0	11	6.6	s.	28	nw.	7	9	11	11		.0	.0
Port Arthur	34	59	134	29.89	29.93		76.5		90	28	84	61	8	69	25				4.62	+.5	9	11.4	s.	39	s.	18	5	17	9	5.9	.0	.0
San Antonio	693	111	301	29.16	29.86	−.04	79.2	+4.1	100	22	90	61	30	69	29	68	62	65	3.22	.0	6	11.5	se.	42	ne.	30	8	14	9	5.5	.0	.0

TABLE 2.—*Climatological data for Weather Bureau stations, May 1939*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*	*°F.*	*°F.*	*%*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							66.9	+2.0										63	1.94	−1.8										5.3		
Chattanooga	762	71	214	29.19	29.99	0.00	69.6	+.8	90	25	80	44	4	59	36	60	55	67	4.55	+.8	16	7.1	se.	28	se.	18	6	7	18	6.8	0.0	0.0
Knoxville	995	66	84	28.96	30.00	+.01	68.6	+1.4	90	24	80	42	3	58	35	60	54	66	1.03	−2.7	13	4.9	w.	24	w.	28	9	11	11	5.5	.0	.0
Memphis	399	78	86	29.53	29.95	−.01	70.8	+.2	88	17	78	51	14	63	22	62	57	67	4.51	+.3	9	6.9	sw.	29	sw.	8	8	11	12	5.8	.0	.0
Nashville	546	168	188	29.42	30.00	+.02	67.8	−.4	88	25	78	43	4	58	34	60	55	69	1.98	−1.9	12	7.8	s.	28	nw.	28	7	8	16	6.1	.0	.0
Lexington	989	6	----	28.96	30.02	+.03	66.6	+2.3	94	26	79	35	3	54	37	----	----	----	2.00	−1.8	9	----	sw.	----	----	----	17	10	4	----	.0	.0
Louisville	525	106	120	29.42	29.98	.00	67.9	+1.3	91	24	78	40	3	58	31	59	53	63	.96	−2.8	7	7.7	sw.	26	w.	28	13	12	6	4.5	.0	.0
Evansville	431	76	116	29.51	29.97	.00	68.8	+2.1	93	24	78	42	2	59	27	59	52	61	2.56	−1.3	10	7.6	s.	40	sw.	8	9	10	12	5.6	.0	.0
Indianapolis	822	98	129	29.10	29.98	+.01	66.8	+3.9	92	25	77	37	2	56	29	56	48	56	.88	−3.0	5	7.5	sw.	23	nw.	9	8	15	8	5.1	.0	.0
Terre Haute	575	63	149	29.35	29.96	----	68.3	----	93	24	80	38	2	57	34	57	50	58	1.94	−1.9	8	8.9	se.	25	se.	19	13	12	6	4.4	.0	.0
Cincinnati	627	11	51	29.32	29.99	.00	66.5	+3.4	90	25	77	36	3	56	32	57	51	66	2.41	−1.3	11	6.3	sw.	22	w.	21	10	12	9	5.3	.0	.0
Columbus	822	90	110	29.12	29.99	+.01	66.2	+3.9	91	26	78	34	1	55	33	56	49	58	.33	−3.3	7	8.1	s.	31	sw.	9	10	14	7	5.0	.0	.0
Dayton	900	186	213	29.04	29.98	----	65.5	+2.9	92	25	76	35	1	55	30	56	49	59	2.56	−1.0	8	8.7	sw.	33	sw.	28	11	15	5	4.9	.0	.0
Elkins	1,947	65	83	28.00	30.02	+.02	60.8	+1.6	88	26	74	28	4	48	39	53	48	68	1.35	−2.7	8	5.1	n.	21	sw.	9	4	16	11	6.3	.0	.0
Parkersburg	637	77	84	29.31	29.98	−.01	66.1	+2.3	92	26	78	34	1	54	36	57	50	62	.53	−2.8	5	5.4	se.	17	s.	8	12	15	4	4.2	.0	.0
Pittsburgh [1]	1,273	39	54	28.64	29.98	−.01	64.0	+1.6	92	26	76	33	1	52	33	55	48	59	1.48	−1.7	10	9.2	sw.	29	sw.	9	10	13	8	4.8	.0	.0
Lower Lake Region							60.0	+2.6										62	1.47	−1.8										4.9		
Buffalo	768	243	280	29.14	29.97	.00	55.6	+1.0	83	26	64	36	1	48	27	49	44	69	1.97	−1.1	5	12.7	sw.	45	sw.	10	10	13	8	4.9	.0	.0
Canton	448	10	61	29.46	29.94	----	55.8	−.4	87	27	67	29	3	44	32	49	43	63	2.56	−.4	9	8.1	w.	35	w.	10	6	14	11	6.1	.0	.0
Ithaca	836	77	100	29.07	29.97	----	60.8	+3.3	89	7	74	31	3	48	50	52	45	61	1.84	−1.6	9	7.7	nw.	25	s.	9	9	10	12	5.7	.0	.0
Oswego	335	71	85	29.59	29.96	−.01	55.4	+.2	84	27	65	37	13	46	41	48	42	65	1.33	−1.7	10	7.6	n.	24	n.	18	11	7	13	5.9	.0	.0
Rochester	523	86	102	29.41	29.98	+.01	59.8	+2.7	90	27	69	37	3	50	36	50	42	55	.64	−2.3	8	8.4	sw.	34	sw.	10	11	12	8	4.6	.0	.0
Syracuse	596	65	79	29.33	29.97	−.01	60.8	+3.1	91	27	71	34	3	50	43	----	----	----	.55	+2.4	5	6.6	nw.	22	w.	23	12	10	9	5.1	.0	.0
Erie	714	57	81	29.21	29.98	.00	59.8	+3.0	86	27	68	37	2	52	31	53	46	63	2.72	−.7	5	7.3	sw.	23	sw.	10	14	13	4	4.0	.0	.0
Cleveland	762	267	318	29.17	29.98	.00	61.6	+3.7	87	27	70	37	2	53	30	53	46	60	1.48	−1.6	6	12.3	sw.	37	sw.	27	14	12	5	4.1	.0	.0
Sandusky	629	5	67	29.30	29.98	.00	62.8	+3.6	92	31	73	40	3	53	41	----	----	----	1.08	−2.1	9	8.1	sw.	22	sw.	10	10	11	10	5.2	.0	.0
Toledo	628	79	87	29.31	29.99	+.02	63.0	+3.6	89	31	73	35	1	53	40	54	47	60	1.43	−2.1	8	9.3	sw.	29	w.	10	16	11	4	4.0	.0	.0
Fort Wayne	857	69	84	29.06	29.98	----	63.6	+4.0	88	25	75	36	1	52	38	54	47	58	1.07	−2.8	6	8.5	sw.	25	w.	10	6	19	6	5.1	.0	.0
Detroit [1]	626	5	78	29.29	29.98	+.01	61.4	+3.4	91	31	73	33	2	50	43	53	47	63	.97	−2.2	9	9.5	sw.	26	w.	10	12	12	7	4.6	.0	.0
Upper Lake Region							55.6	+3.0										69	2.48	−0.8										5.3		
Alpena	609	13	89	29.30	29.96	−.01	53.2	+2.7	89	30	63	30	12	44	41	47	42	71	3.91	+.9	12	10.1	se.	28	nw.	23	9	13	9	5.4	.0	.0
Escanaba	612	41	49	29.30	29.96	−.01	50.6	+1.0	85	30	59	28	12	42	32	46	42	75	2.82	−.1	10	11.1	s.	32	sw.	9	9	11	11	5.9	T	.0
Grand Rapids	707	70	244	29.20	29.96	−.01	62.2	+4.2	89	31	73	34	12	52	33	53	46	60	1.12	−2.3	13	10.9	sw.	37	sw.	27	16	10	5	4.2	.0	.0
Lansing	878	5	90	29.03	29.97	----	60.3	+3.4	87	31	72	30	12	49	39	54	50	72	2.07	−1.4	8	7.8	sw.	23	sw.	27	10	16	5	4.5	.0	.0
Marquette	734	44	69	29.15	29.96	−.01	51.0	+2.0	86	6	61	31	11	41	40	46	41	74	3.08	+.1	12	7.9	nw.	26	sw.	29	7	10	14	6.4	.0	.0
Sault Ste. Marie [1]	724	5	33	29.16	29.96	+.01	50.6	+1.6	83	7	62	27	16	39	40	46	42	74	2.46	−.6	15	----	nw.	----	----	----	6	10	15	6.7	.0	.0
Chicago	673	7	131	29.25	29.97	+.01	61.4	+3.9	88	31	71	39	3	52	33	53	47	67	3.66	+.1	9	9.7	sw.	25	n.	17	16	11	4	3.9	.0	.0
Green Bay	617	109	141	29.27	29.94	−.01	58.8	+3.9	92	30	70	32	1	48	31	51	44	63	2.39	−1.1	7	11.2	s.	30	nw.	10	9	10	12	5.4	.0	.0
Milwaukee	681	97	221	29.22	29.95	−.01	57.9	+3.8	90	30	68	36	2	48	38	50	43	64	1.40	−2.0	10	12.1	sw.	32	n.	17	14	7	10	4.6	.0	.0
Duluth	1,133	5	47	28.69	29.91	−.05	50.4	+3.1	95	30	61	30	1	40	44	44	39	73	1.93	−1.3	13	12.8	ne.	35	w.	9	8	13	10	5.7	.0	.0
North Dakota							60.8	+6.8										56	1.30	−1.1										5.1		
Moorhead, Minn	940	50	58	28.85	29.85	−.09	62.2	+7.1	101	30	76	28	11	48	38	51	42	54	.48	−2.4	7	9.6	s.	29	nw.	9	10	13	8	5.2	.0	.0
Lemmon, S. Dak	2,602	4	38	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Bismarck	1,677	8	57	28.09	29.85	−.07	62.0	+7.5	98	30	75	32	11	49	42	51	41	54	1.57	−.8	11	9.9	nw.	34	nw.	5	10	13	8	5.5	.0	.0
Devils Lake	1,478	11	44	28.30	29.86	−.08	59.2	+6.6	97	30	72	25	11	46	42	49	40	57	1.54	−.5	9	10.8	ne.	33	nw.	9	4	17	10	6.2	.0	.0
Grand Forks	832	11	71	----	----	----	60.3	+6.6	100	30	75	22	11	45	44	51	43	----	.91	−1.7	7	10.4	s.	----	----	----	----	----	----	----	.0	.0
Williston	1,878	42	50	27.90	29.85	−.08	60.2	+6.2	89	29	72	29	11	49	34	50	41	57	1.98	−.1	15	9.3	w.	35	nw.	5	19	7	5	3.6	.0	.0
Upper Mississippi Valley							66.4	+4.8										61	2.81	−1.3										4.9		
Minneapolis and St. Paul, Minn. [1]	838	32	61	28.98	29.88	−.06	64.0	+6.3	95	30	76	35	12	52	34	54	47	59	3.55	−.1	8	11.5	s.	44	s.	25	10	12	9	5.5	.0	.0
Springfield, Minn	1,025	4	42	----	----	----	65.8	----	97	30	79	34	11	53	40	54	46	----	2.82	----	7	7.6	s.	----	----	----	----	----	----	----	.0	.0
La Crosse	714	11	48	29.15	29.91	−.03	65.0	+5.7	92	30	77	38	12	53	35	55	48	59	2.03	−1.7	3	5.7	s.	19	w.	9	11	11	9	4.8	.0	.0
Madison	974	70	78	28.90	29.93	−.03	62.4	+4.8	90	30	73	34	1	52	30	54	47	62	1.64	−2.2	7	8.1	s.	25	ne.	15	11	9	11	5.4	.0	.0
Charles City	1,015	10	51	28.84	29.92	−.02	65.0	+7.2	93	30	78	35	11	52	41	54	46	58	2.44	−1.9	6	6.9	se.	26	se.	25	13	17	1	3.7	.0	.0
Davenport	606	66	161	29.28	29.94	−.01	66.8	+5.5	91	24	78	38	2	56	38	57	50	61	2.65	−1.3	7	9.4	sw.	27	nw.	14	10	12	9	5.2	.0	.0
Des Moines	860	5	99	29.00	29.89	−.04	68.4	+7.1	97	24	81	43	11	56	37	57	49	55	1.79	−2.8	7	9.6	s.	30	sw.	6	12	10	9	5.0	.0	.0
Dubuque	699	60	79	29.18	29.92	−.03	66.0	+5.7	92	31	77	38	1	54	37	56	48	57	1.44	−2.8	6	6.3	s.	18	s.	6	15	9	7	4.5	.0	.0
Keokuk	614	64	78	29.28	29.93	−.01	67.4	+3.6	92	24	77	41	2	57	31	59	53	64	5.80	+1.9	10	6.8	sw.	31	w.	27	10	8	13	5.6	.0	.0
Cairo	358	87	93	29.58	29.96	.00	69.0	+.6	88	24	78	48	2	61	26	61	56	69	3.62	−.1	11	7.4	s.	27	s.	25	7	9	15	6.3	.0	.0
Peoria	609	11	45	29.30	29.96	.00	66.2	+4.5	93	24	78	37	3	55	38	57	52	65	4.48	+.4	10	6.0	s.	16	nw.	27	14	15	2	3.7	.0	.0
Springfield, Ill	636	5	191	29.28	29.95	.00	68.0	+4.8	94	24	79	37	2	57	33	58	51	61	1.62	−2.8	9	10.5	s.	24	ne.	1	10	10	11	5.3	.0	.0
St. Louis	568	179	303	29.34	29.94	−.01	69.2	+2.2	91	24	78	43	2	60	28	59	53	62	2.64	−1.7	12	10.8	s.	28	sw.	6	15	10	6	4.0	.0	.0
Missouri Valley							68.2	+6.3										57	3.01	−1.1										4.7		
Columbia, Mo	784	6	66	29.10	29.93	−.01	68.1	+3.8	92	24	78	46	13	58	29	----	----	----	5.00	+.5	9	7.0	s.	27	n.	8	12	10	9	5.0	.0	.0
Kansas City [1]	750	32	45	29.11	29.90	−.02	70.1	+5.3	97	24	80	42	13	60	34	59	52	59	2.85	−1.8	10	8.1	sw.	27	sw.	6	13	9	9	4.9	.0	.0
St. Joseph	967	11	49	28.88	29.89	----	70.0	+5.8	97	24	81	41	13	59	36	58	50	57	1.38	−3.3	10	7.4	s.	24	sw.	7	14	11	6	3.8	.0	.0
Springfield, Mo	1,324	5	78	28.55	29.94	+.01	66.8	+2.3	90	23	77	45	14	57	33	59	53	68	6.64	+1.4	11	7.7	se.	24	e.	20	14	7	10	4.7	.0	.0
Topeka	987	65	87	28.85	29.88	----	70.6	+6.3	99	30	82	42	13	59	41	59	51	56	1.33	−3.2	8	8.9	s.	27	s.	22	9	15	7	4.8	.0	.0
Lincoln	1,189	11	81	28.63	29.86	−.05	69.6	+7.9	98	30	82	41	13	57	40	58	49	53	1.61	−2.5	5	9.5	s.	30	s.	6	10	11	10	5.0	.0	.0
Omaha [1]	982	31	44	28.85	29.88	−.04	69.4	+7.0	99	24	82	42	11	57	41	57	48	54	1.65	−2.1	9	10.5	s.	39	se.	22	11	13	7	4.9	.0	.0
Valentine	2,598	47	54	27.19	29.86	−.04	63.8	+7.6	92	29	76	38	13	51	41	53	44	58	3.44	+.6	14	10.0	n.	32	nw.	22	6	16	9	5.6	.0	.0
Sioux City	1,138	64	106	----	29.86	−.06	69.0	+8.6	98	24	82	41	11	56	38	----	----	52	2.50	−1.6	6	9.4	s.	32	se.	25	16	6	9	----	.0	.0
Huron [1]	1,289	27	41	28.49	29.85	−.07	65.1	+8.7	97	30	79	31	11	51	50	54	45	55	3.66	+.7	10	14.6	s.	63	ne.	23	14	12	5	3.9	.0	.0

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau stations, May 1939*

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01 inch or more	Wind: Average hourly velocity	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern Slope							**57.8**	**+5.3**										**54**	**1.82**	**−0.5**										**5.3**		
Havre	2,507	11	67	27.29	29.90	0.00	59.2	+5.8	91	29	72	32	10	46	45	47	36	48	1.28	−.8	10	10.0	w.	35	w.	8	9	15	7	4.9	0.0	0.0
Helena	4,124	85	111	25.76	29.91	−.02	56.0	+4.4	84	15	67	34	1	45	35	45	34	48	1.59	−.7	9	9.0	sw.	35	sw.	21	8	10	13	6.0	T	.0
Missoula	3,263	80	91	.....	.....	.....	57.7	+4.9	89	15	71	33	6	44	42	...	...	...	2.31	+.3	10	7.0	w.	33	nw.	16	8	15	8	5.3	.0	.0
Kalispell	2,973	48	56	26.90	29.93	+.05	54.7	+3.3	85	15	67	31	6	42	38	46	38	60	1.09	−.4	10	6.6	w.	26	sw.	17	9	5	17	6.2	.0	.0
Miles City	2,371	48	55	27.41	29.86	−.05	61.8	+5.1	94	29	74	36	8	49	39	50	39	51	1.35	−.9	11	7.1	s.	43	nw.	5	11	10	10	4.9	.0	.0
Rapid City	3,259	50	58	26.54	29.86	−.04	62.5	+8.5	97	29	74	40	8	51	38	51	41	52	1.04	−2.5	12	7.9	n.	36	nw.	5	12	9	10	5.2	.0	.0
Cheyenne[1]	6,144	5	39	23.93	29.86	+.01	54.4	+4.1	84	29	69	28	13	40	39	43	34	55	1.69	−.7	10	11.0	nw.	32	nw.	9	10	5	16	6.1	T	.0
Lander	5,352	60	68	24.62	29.86	−.02	56.4	+5.2	87	29	71	32	8	42	44	44	33	50	2.80	+.5	6	6.2	sw.	47	sw.	19	14	11	6	4.8	T	.0
Sheridan	3,790	10	47	26.05	29.91	.....	57.3	.....	90	29	73	28	8	42	46	47	39	59	3.82	+1.2	7	5.1	nw.	30	nw.	19	11	10	10	5.1	T	.0
Yellowstone Park	6,241	12	46	23.88	29.99	+.08	49.8	+5.2	77	29	63	26	12	36	38	40	31	57	.58	−1.2	8	8.0	sw.	31	sw.	18	8	14	9	5.5	T	.0
North Platte	2,821	11	51	26.98	29.86	−.02	65.2	+6.5	92	24	78	38	7	52	44	54	46	60	2.51	−.3	11	8.2	s.	25	ne.	2	14	10	7	4.4	.0	.0
Middle Slope							**66.9**	**+4.4**										**54**	**2.42**	**−1.0**										**4.6**		
Denver	5,292	106	113	24.68	29.85	+.01	61.5	+5.3	90	22	74	33	8	49	33	47	34	43	1.03	−1.2	8	8.4	s.	32	n.	7	11	13	7	4.5	T	.0
Pueblo	4,690	79	86	25.24	29.86	+.03	62.0	+2.8	91	22	76	40	9	48	45	48	37	50	1.51	−.1	7	7.5	e.	30	nw.	2	16	8	7	4.4	.0	.0
Chadron, Nebr.	3,439	4	58	.....	.....	.....	.....	.....	...	...	...	...	...	...	...	...	...	...	.....	.....	...	.....	.....	...	.....	...	...	...	...	.....	.....	.....
Concordia	1,392	50	58	28.42	29.87	−.04	68.6	+5.4	95	24	81	41	13	56	40	58	50	56	3.56	−.6	9	8.2	s.	29	nw.	20	11	13	7	4.6	.0	.0
Dodge City	2,509	10	86	27.30	29.85	−.02	67.8	+4.3	99	23	81	40	9	55	49	56	47	55	2.29	−.6	6	12.4	s.	43	n.	6	13	12	6	4.5	.0	.0
Wichita	1,358	85	93	28.47	29.88	−.02	69.4	+4.3	97	23	80	43	13	58	29	58	51	58	3.25	−1.2	7	10.4	se.	33	s.	6	14	9	8	4.5	.0	.0
Oklahoma City	1,214	10	47	28.61	29.86	−.03	72.1	+4.4	99	23	83	50	13	61	33	61	55	63	2.88	−2.0	7	9.3	s.	26	s.	10	1_2	11	8	5.0	.0	.0
Southern Slope							**73.0**	**+2.4**										**54**	**2.70**	**0.0**										**4.6**		
Abilene	1,738	10	56	28.07	29.84	−.03	75.4	+3.4	103	20	87	52	13	63	34	63	56	60	6.57	+2.6	15	10.1	s.	36	nw.	27	1^0	9	12	5.3	.0	.0
Amarillo	3,676	10	49	26.20	29.86	+.02	67.6	+3.5	96	22	80	41	12	55	36	54	44	53	1.75	−1.0	7	9.2	se.	24	w.	25	1^2	12	7	4.8	.0	.0
Del Rio	960	63	71	28.83	29.79	−.06	79.3	+2.3	100	8	90	60	14	69	40	67	59	59	1.59	−1.3	6	10.9	se.	31	e.	4	^{8}	16	7	5.1	.0	.0
Roswell	3,566	75	85	26.27	29.81	−.01	69.7	+.3	97	22	84	46	13	55	41	54	40	43	.88	−.2	4	8.4	s.	35	ne.	28	1^9	9	3	3.1	.0	.0
Southern Plateau							**67.8**	**+2.7**										**34**	**0.11**	**−0.4**										**2.6**		
El Paso	3,778	82	101	26.09	29.77	−.01	75.0	+3.5	96	19	89	54	9	61	38	52	29	23	.01	−.3	1	8.7	w.	26	nw.	29	20	9	2	2.5	.0	.0
Albuquerque[1]	5,314	5	39	24.98	29.78	.....	65.5	+2.2	93	22	82	42	26	49	45	47	28	33	.14	−.5	2	9.6	nw.	37	nw.	2	20	7	4	2.9	.0	.0
Santa Fe	7,013	38	53	23.23	29.84	+.03	58.1	+2.4	80	22	71	37	13	45	35	42	26	38	.53	−.7	5	6.6	e.	24	ne.	28	15	11	5	3.9	.0	.0
Flagstaff	6,907	10	59	23.32	29.80	+.02	52.5	+1.8	79	29	70	26	24	35	45	42	...	52	.08	−1.1	1	9.3	nw.	29	sw.	23	16	13	2	3.6	.0	.0
Phoenix	1,107	39	51	28.64	29.77	−.01	78.8	+3.8	105	29	95	56	24	63	38	54	31	21	.00	−.1	0	6.2	e.	18	w.	23	23	5	3	2.1	.0	.0
Yuma	141	9	54	29.64	29.78	−.01	79.0	+2.8	107	29	96	57	12	62	43	59	41	34	.00	.0	0	6.3	w.	26	nw.	21	29	1	1	.6	.0	.0
Independence	3,957	5	26	25.89	29.88	+.04	65.4	+2.4	92	28	79	42	23	52	36	48	27	...	T	−.2	0	.....	n.	...	.....	...	23	6	2	...	.0	.0
Middle Plateau							**59.8**	**+4.2**										**40**	**0.64**	**−0.2**										**4.1**		
Reno	4,527	61	76	25.44	29.93	+.02	58.6	+4.4	88	29	73	36	19	45	38	45	33	44	.64	.0	4	7.6	w.	27	w.	21	16	13	2	3.4	T	.0
Tonopah	6,090	12	20	.....	.....	.....	57.8	.....	88	29	70	32	23	46	30	44	32	44	.59	.....	7	.....	se.	...	.....	...	...	...	...	...	T	.0
Winnemucca	4,344	18	56	25.56	29.90	−.01	58.6	+4.7	92	29	75	29	24	42	47	44	29	38	.82	−.1	5	7.3	sw.	30	w.	18	11	13	7	4.8	.0	.0
Modena	5,473	10	46	24.56	29.82	.00	56.3	+2.8	86	29	72	30	25	40	42	43	28	40	.77	.0	10	10.2	sw.	35	sw.	21	13	8	10	4.7	.1	.0
Salt Lake City[1]	4,227	32	46	25.65	29.85	−.01	60.5	.....	91	29	75	35	20	46	40	47	34	44	.51	.....	5	9.9	se.	42	w.	22	14	13	4	4.3	.0	.0
Grand Junction	4,602	60	68	25.29	29.81	−.02	65.8	+4.7	90	29	79	43	7	52	35	48	29	31	.34	−.5	2	7.5	se.	34	sw.	31	14	17	0	3.5	.0	.0
Northern Plateau							**60.4**	**+3.8**										**45**	**0.39**	**−0.9**										**5.0**		
Baker	3,471	36	54	26.43	29.97	+.01	55.6	+3.9	87	15	70	30	6	41	45	45	34	52	.87	−.7	7	6.6	n.	22	n.	4	9	14	8	5.1	.0	.0
Boise	2,739	79	87	27.10	29.93	−.01	61.8	+4.7	91	28	76	36	6	48	38	48	35	43	.11	−1.3	3	6.1	nw.	21	nw.	11	11	13	7	4.7	.0	.0
Pocatello[1]	4,478	5	31	25.42	29.88	−.01	58.3	.....	91	29	74	29	20	43	44	45	33	46	.37	.....	5	10.3	sw.	33	w.	19	10	13	8	4.9	.0	.0
Spokane	1,929	101	110	27.92	29.95	−.01	58.9	+3.4	92	15	72	36	5	46	42	47	34	46	.30	−1.1	4	7.6	s.	24	sw.	6	12	11	8	4.9	.0	.0
Walla Walla	991	57	65	28.90	29.96	.00	62.8	+3.2	93	14	75	41	5	51	38	50	36	42	.35	−1.3	6	5.8	s.	22	sw.	15	12	8	11	5.4	.0	.0
Yakima	1,076	58	67	28.82	29.97	.....	62.8	+3.8	94	14	76	34	5	50	40	49	35	40	.32	−.3	3	7.3	nw.	24	w.	4	12	9	10	4.9	.0	.0
North Pacific Coast Region							**56.9**	**+2.6**										**69**	**1.74**	**−0.6**										**6.2**		
North Head	211	8	56	29.85	30.08	+.05	53.4	+2.5	80	13	58	44	9	48	26	50	47	82	1.84	−1.1	12	13.3	n.	45	s.	28	4	14	13	6.9	.0	.0
Seattle	125	90	321	29.91	30.04	+.03	57.6	+3.1	86	13	66	43	5	49	33	50	43	63	1.27	−.6	10	8.1	n.	28	sw.	28	5	12	14	6.7	.0	.0
Tacoma	263	172	201	29.85	30.06	+.04	56.3	+2.2	82	14	65	40	5	47	30	...	...	...	1.38	−.7	11	8.2	n.	26	sw.	6	7	12	12	6.1	.0	.0
Tatoosh Island	86	9	55	29.97	30.07	+.06	51.1	+1.5	65	13	55	44	1	47	18	48	45	81	3.87	−.1	17	9.5	sw.	42	s.	28	9	7	15	6.5	.0	.0
Medford	1,329	29	58	28.61	30.01	.....	59.7	+2.0	95	14	75	33	5	44	48	50	42	62	1.22	.0	9	.....	nw.	...	.....	...	11	9	11	4.9	.0	.0
Portland, Oreg.	154	68	106	29.89	30.05	+.02	60.6	+3.7	96	13	71	40	5	50	39	52	45	62	1.08	−1.1	10	6.0	nw.	17	sw.	16	8	5	18	6.4	.0	.0
Roseburg	510	45	76	29.49	30.04	+.01	59.5	+3.5	96	13	73	35	5	46	50	51	43	63	1.54	−.4	7	4.9	n.	20	sw.	21	10	5	16	5.9	.0	.0
Middle Pacific Coast Region							**61.3**	**+1.7**										**63**	**1.92**	**+0.7**										**4.7**		
Eureka	60	72	88	30.00	30.07	+.02	54.0	+2.0	84	13	60	41	2	48	35	50	47	79	1.85	.0	4	8.0	n.	24	n.	4	8	10	13	6.1	.0	.0
Redding[1]	722	20	34	.....	.....	.....	67.6	+1.2	97	28	79	44	21	56	35	53	39	42	4.28	+2.8	6	8.3	nw.	25	nw.	29	13	17	7	4.4	.0	.0
Sacramento	66	92	115	29.87	29.94	.00	66.7	+3.4	100	29	81	42	6	52	41	55	45	55	.92	+.2	4	8.2	s.	27	sw.	18	19	10	2	3.0	.0	.0
San Francisco	155	112	132	29.83	30.00	+.01	57.0	+.2	73	28	62	48	1	52	20	52	48	77	.63	−.2	3	11.0	w.	29	w.	13	11	10	10	5.2	.0	.0
South Pacific Coast Region							**65.1**	**+1.7**										**62**	**0.02**	**−0.4**										**4.1**		
Fresno	327	97	105	29.58	29.93	+.01	69.4	+2.3	101	29	83	46	6	55	34	55	42	44	.02	−.4	1	7.8	nw.	25	nw.	18	21	8	2	2.5	.0	.0
Los Angeles	338	159	191	29.60	29.97	+.02	63.6	+1.4	89	25	72	52	22	56	26	55	50	68	.02	−.4	2	5.7	sw.	16	sw.	23	11	13	7	4.5	.0	.0
San Diego	87	62	70	29.87	29.96	+.01	62.2	+1.4	80	25	68	54	23	57	22	56	53	74	.01	−.3	1	7.2	w.	17	nw.	24	12	10	9	5.2	.0	.0
West Indies																																
San Juan, P. R.	82	9	54	29.92	30.01	.....	77.2	−1.4	87	1	82	71	24	73	13	...	...	...	9.77	+4.5	19	11.9	e.	27	e.	2	5	23	3	5.2	.0	.0

TABLE 2.—*Climatological data for Weather Bureau stations, May 1939*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Panama Canal	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Balboa Heights	118	6	92		[2]29.82	−0.01	82.4	+1.7	94	2	90	72	15	75	19			[3]82	4.61	−3.4	18	6.1	nw.	22	nw.	3	0	24	7	6.5	0.0	0.0
Cristobal	30	6	97		[2]29.84	.00	82.8	+2.1	88	16	87	75	14	79	11	76	74	[3]78	6.28	−6.3	15	10.1	n.	21	n.	20	2	14	15	7.0	.0	.0
Alaska																																
Fairbanks	454	11	87		[2]29.83		47.1	+.1	71	18	58	20	1	36	33				.89	+.3	10	6.5	s.	30	ne.	25	1	14	16		.4	.0
Juneau	80	96	116	[2]29.84	[2]29.93		46.4	−1.4	64	19	52	32	8	40	25	42	38	74	5.63	+.5	29	7.1	s.	26	se.	19	0	4	27	8.9	1.6	.0
Nome	22	5	57																													
Hawaiian Islands																																
Honolulu	38	86	100	30.00	30.04		74.3	−.5	81	14	78	65	7	70	11	68	65	74	1.46	−.3	13	10.2	e.	25	ne.	18	6	16	9	5.8	.0	.0

[1] Observations taken at airport. [2] Observations taken bihourly. [3] Pressure not reduced to a mean of 24 hours.

TABLE 3.—*Data furnished by the Canadian Meteorological Service, May 1939*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*In.*	*In.*	*In.*
Cape Race, Newfoundland	99				37.7	−2.3	44.5	30.9	56	23	5.43	+1.07	0.0
Sydney, Cape Breton Island	48	29.80	29.93	−0.04	43.8	−2.4	54.2	33.4	74	26	2.45	−1.00	T
Halifax, Nova Scotia	88	29.69	29.95	−.02	48.9	−.4	57.3	40.5	75	30	4.73	+.56	.0
Yarmouth, Nova Scotia	65	29.85	29.96	−.01	47.4	−.6	55.5	39.2	63	30	2.07	−1.48	.0
Charlottetown, Prince Edward Island	38	29.87	29.95	.00	45.8	−2.0	54.5	37.2	71	30	4.51	+1.94	T
Chatham, New Brunswick	28	29.81	29.92	−.03	46.8	−2.6	58.9	34.6	74	24	1.38	−1.82	.0
Father Point, Quebec	20	29.90	29.92	.00	44.4	.0	52.3	36.4	67	31	2.10	−.73	.0
Quebec, Quebec	296	29.61	29.93	−.01	51.4	+.5	60.9	41.8	81	32	3.04	−.29	.0
Doucet, Quebec	1,236	28.56	29.91	−.03	44.8	+1.0	56.9	32.7	75	12	3.53	+.62	.2
Montreal, Quebec	187												
Ottawa, Ontario	236	29.56	29.93	+.01	54.9	−.7	68.5	43.3	87	29	2.12	−.56	.0
Kingston, Ontario	285	29.66	29.97	+.02	53.4	+.1	62.9	43.9	76	31	1.42	−1.52	.0
Toronto, Ontario	379	29.55	29.96	−.01	57.9	+3.6	67.4	48.3	86	35	1.49	−1.43	.0
Cochrane, Ontario	930	(*)	(*)	(*)	47.0	+.5	59.5	34.6	81	20	3.50	+1.28	2.3
White River, Ontario	1,244	28.62	29.97	+.01	47.2	−.2	59.8	34.5	85	19	2.01	−.19	.3
London, Ontario	808	29.11	29.98	.00	56.5	+.7	68.7	44.3	86	29	1.80	−1.46	.0
Southampton, Ontario	656	29.25	29.96	.00	52.4	+1.5	62.2	42.7	81	27	3.09	+.48	.0
Parry Sound, Ontario	688	29.31	30.00	+.04	52.8	+.8	62.8	42.9	82	28	2.27	−.66	.0
Port Arthur, Ontario	644	29.23	29.95	−.02	47.0	.0	57.3	36.7	84	23	2.24	+.14	.0
Winnipeg, Manitoba	760	29.02	29.88	−.10	55.6	+3.6	67.6	43.5	94	22	1.37	−.82	.0
Minnedosa, Manitoba	1,690	28.08	29.88	−.06	54.9	+5.1	67.4	42.4	88	22	2.47	+.69	.0
Le Pas, Manitoba	860	28.94	29.91	−.07	49.0	+1.3	61.3	36.7	79	24	1.11	−.25	.0
Qu'Appelle, Saskatchewan	2,115	27.61	29.87	−.06	55.0	+4.8	67.2	42.8	85	24	1.36	−.74	.0
Moose Jaw, Saskatchewan	1,759	27.90	29.88	−.02	56.8	+5.5	68.8	44.7	88	29	1.67	−.31	.0
Swift Current, Saskatchewan	2,392	27.08	29.89	−.03	54.0	+2.7	66.0	42.0	84	25	3.24	+1.33	.0
Medicine Hat, Alberta	2,365	27.41	29.89	+.01	57.0	+1.8	70.5	43.6	88	24	1.22	−.40	.0
Calgary, Alberta	3,540	26.27	29.93	+.01	52.2	+3.3	65.2	39.1	85	24	1.42	−.75	.0
Banff, Alberta	4,521				47.8	+2.6	60.6	34.9	77	20	1.03	−1.01	T
Prince Albert, Saskatchewan	1,450	28.36	29.91	−.04	53.1	+3.3	64.1	42.1	82	29	1.00	−.43	.0
Battleford, Saskatchewan	1,592	28.12	29.85	−.07	54.2	+4.8	67.3	41.2	86	29	1.07	−.55	.0
Edmonton, Alberta	2,150	27.54	29.88	.00	52.8	+1.7	63.9	41.8	86	23	5.28	+3.57	.0
Kamloops, British Columbia	1,262	28.60	29.94	+.01	59.4	+1.7	72.3	46.5	91	33	.86	−.05	.0
Victoria, British Columbia	230	29.81	30.05	+.02	54.3	+1.3	61.9	46.7	78	42	1.04	−.05	.0
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20	30.04	30.07	+.03	50.1	+.9	56.4	43.9	71	35	5.79	+.43	.0
Prince Rupert, British Columbia	170	29.81	30.00	+.01	48.7	+.4	54.4	43.0	67	36	9.32	+4.00	.0
St. George's, Bermuda	158		30.10	+.04	72.4	+3.1	77.5	67.2	83	61	2.30	−1.74	.0

*Pressure readings discontinued.

LATE REPORTS FOR APRIL 1939

Cape Race, Newfoundland	99				32.0	−0.8	37.3	26.6	43	14	5.32	+1.23	7.5
Quebec, Quebec	296	29.59	29.92	−0.04	34.8	−1.6	40.9	28.6	54	17	3.68	+1.26	21.0
Banff, Alberta	4,521				40.3	+3.5	53.5	27.1	77	13	.45	−.64	3.4
Prince Rupert, British Columbia	170	29.84	30.03	−.09	42.8	−.5	47.5	38.2	54	30	11.43	+4.48	6.2

TABLE 4.—*Severe local storms, May 1939*

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials]

[The table herewith contains such data as has been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Cairo-St. Michael, Nebr.	2	6:30 to 7:45 p. m.	[1] 8-10		$5,000	Wind and hail	Damage mainly to roofs, gardens, and early fruits.
Rankin, Tex.	3	5:30 p. m.	[1] 3		30,000	Hail	No details.
Crawford County, Iowa	4	4:30-6 p. m.	[1] 2		42,000	Hail and flood	Property damaged; loss to fruit and crops from hail, $31,000, from flooding, $11,000.
Miles City, Mont., and vicinity.	5	3:48 p. m.			10,000	Straight-line wind and dust.	Wind from the northwest, accompanied the first 10 to 15 minutes by dust, reduced visibility to less than 50 feet. 2 women injured; trees blown down; damage to electric signs, fences, roofs, and automobiles.
Monroe, Nebr.	6	4 p. m.	[1] 3		5,000	Rain and hail	Hail completely covered the ground causing small crop loss; ground washed by heavy rain; several small buildings inundated.
Ness County, Kans.	6	4-8 p. m.			10,000	Heavy hail	Property loss estimate of 2 storms. Loss to wheat and gardens over almost the entire county.
Jetmore, Kans.	6	6 p. m.	[1] 4		15,000	do	Chief damage to property; path 4 miles long.
Jetmore, Kans., vicinity of.	6	6:45 p. m.	[1] 1	0	15,000	Tornado	Several vortex clouds reported; damage to farm property; path 3 miles long.
Jetmore, Kans., 16 miles southwest.	6	7 p. m.	[1] 2	0	10,000	do	Damage to farm property; path 21 miles long.
Garfield, Kans., and vicinity.	6	8:15 p. m.	[1] 5		15,000	Wind	2 persons injured. Roofs, windmills, and small buildings damaged; path 15 miles long.
Rule, Tex.	7	1 p. m.	12	0	2,000	Tornado	4 tornado clouds observed.
Fellsmere, Fla.	7	3 p. m.	50-100	0		do	Several houses unroofed, 2 lifted off their foundations. Storm moved west-northwest; path 1 mile long.
Putnam to Scranton, Tex., and vicinities.	7	5:10 p. m.	100	0	6,500	do	4 farm residences damaged or destroyed; small crop loss.
Fayetteville, Tex., and vicinity.	7	6 p. m.	300		20,000	Hail	Roofs destroyed by hailstones as large as baseballs; buildings and fences damaged; windows broken; poultry and sheep killed.
Carmine, Tex.	7	6:30 p. m.	[1] 2		700	do	Crop loss, $500; poultry killed, $200.
Waco, Tex.	7	P. m.	[1] 10		500,000	Wind and hail	Hail damaged crops to the extent of $450,000; 1 person injured.
Covington, Ill.	7				8,000	Heavy hail	Loss to crops.
Luling, Tex.	8	6:30 p. m.	[1] 2	2	250,000	Tornado and hail	24 persons injured. $250,000 property damage; much loss to crops, amount not estimated.
Warrick and Dubois Counties, Ind.	8	P. m.		1	10,000	Wind and hail	Several buildings destroyed; trees blown down; loss to crops.
McCormick, S. C.,[2] 4 miles north.	8	do	100	1		Tornado	Several persons injured; trees, 6 inches in diameter twisted off and carried hundreds of feet; 6 houses completely demolished. Man killed when his home blew over leaving 2 members of his family unhurt. Nearby, another dwelling was blown away leaving 8 persons unhurt. Several poultry houses on a farm blown down and 75 chickens killed.
Mobile County, Ala., central portion.	9		[1] 10		10,000	Hail, wind, and rain.	Loss to crops; path 10 miles long.
Sedan, Kans., 10 miles northeast.	10	5-6 p. m.	[1] 15		500	Heavy hail	Considerable damage to gardens and fruit; path 20 miles long.
Montgomery County, Kans.	10	5:30-6:45 p. m.	[1] 2		30,000	do	Chief damage at Independence, mostly to greenhouses, electric signs, and automobile tops; path 2 miles long.
Pryor, Okla.	10	8 p. m.			2,750	do	Loss in wheat, barley, and gardens. Small property damage not included in the estimate given. Width of path as wide as 2 miles and 14 miles long.
Bartlesville, Okla., vicinity of.	10		[1] 4		10,000	do	Considerable damage to grains and gardens. Property damage small, not estimated; path 6 miles long.
Massachusetts and New Hampshire.	11					Dust	Blue Hill Observatory reports this to be the most intense dust storm in this vicinity in 5 years, reducing sunshine 50 percent and visibility to 5 miles.
Gentry and Springtown, Ark.	14	4 a. m.			3,000	Wind	Loss in fruit, $2,000; damage to buildings, $1,000; path 5 miles long.
Tajique, N. Mex.	14	3 p. m.	[1] 12		1,000	Hail	Loss to crops.
Beaver City, Nebr.	14	11:25 p. m.-Midnight.	[1] 1		3,000	do	Damage mostly to roofs.
Georgia: Douglas to Jesup, southeastward into Brantley County.	14				50,000	do	Chief loss in tobacco.
Center Hill, Fla.	15		1,320		25,000	do	Loss to crops. Small property damage not estimated.
Volusia, Lake, and Flagler Counties, Fla.	15				100,000	do	Crop loss, $75,000; property damage, $25,000.
Strawn, Tex.	16	3 p. m.	[1] 1		5,000	do	Chief loss to crops; roofs damaged; windows broken.
Brown County, Tex., northeastern portion.	16	4 p. m.	[1] 4	0	100,000	Tornado and hail	Several persons injured; fruit and grain crops ruined.
Carlsbad, N. Mex.	16	6 p. m.	2,640		45,600	Hail	Crop loss, $5,000; damage to roofs, $600.
Levelland, Tex.	16	8 p. m.	[1] 4			do	About 350 roofs or buildings damaged.
San Jon, N. Mex.	16	11 a. m.-4 p. m.	[1] 8		1,000	do	Loss to crops.
Stevensville, Mont.	16				6,000	Electrical	High school building damaged by fire.
Kingfisher, Okla., 6 miles southwest.	17	1:30 p. m.	[1] 1		5,000	Heavy hail	Loss to wheat, $5,000; small property damage; path 3 miles long.
Putnam City, Okla.	17	3 p. m.	[1] 4		900	do	Damage to school building, $900; additional loss to crops and other property not given; path 4 miles long.
Hewitt, Tex.	17	6:50 p. m.	880	0	10,500	Tornado	2 tornadoes converging, ended as one, with injury to 5 persons; property damage of $10,000 and crop loss of $500.
Comal County, Tex., northern portion.	17	8 p. m.	2,640		7,500	Hail	Crop loss, $7,500; loss to poultry, sheep, and wildlife not estimated.
Schulenburg, Tex., vicinity of.	18	1:30 a. m.	[1] 3		112,000	Wind and hail	Crop loss, $100,000; damage to buildings and poultry killed, $12,000.
Waller, Tex.	18	2 a. m.			3,500	do	$1,500 loss to crops; property damage, $2,000.
Jerome and Twin Falls Counties, Idaho.	18	12:30-1 p. m.	[1] 2-3			Hail	Much loss to young crops. No reliable estimate of property damage available. Path 25 miles long.
Redland, Tex., and vicinity.	18	4:30 p. m.	2,369		5,000	do	Crop loss, $4,000; property damage, $1,000.
Cego, Tex.	18	8:30 p. m.	[1] 8	1	45,000	Wind	3 persons injured; crop loss, $40,000; property damage, $5,000.
Okawville, Ill.	18				6,000	Heavy hail	Loss to crops.
Nowata, Okla., 15 miles northeast.	19					do	Considerable crop loss over a small area.
Junction City, Kans., and vicinity.	20	6-7 a. m.	2,640		18,000	do	Damage to greenhouses, windows, roofs, and automobiles; path 17 miles long.
Mullen to Norway, Nebr.	21	7:30-10 p. m.	[1] 2-10		8,000	Rain, hail, and wind.	Hail worst at Seneca where nearly all roofs were damaged; many windows broken; small crop loss. Railroad grade washed out at Norway.
Clyde, Kans.,[2] and vicinity.	21	P. m.				Wind	Much property damaged; trees uprooted; wires down. A barn moved 2 feet from its foundation; a hayrack carried 100 yards.
Chamberlain and Kimball, S. Dak.	22	1 a. m.			16,000	Wind and hail	Houses and barns destroyed by wind with $15,000 damage; loss to crops because of hail, $1,000.
Eureka Springs, Ark.	22	12:45 p. m.	[1] 2		3,000	Heavy hail	Much damage to vegetation.
Pulaski County, Ark.	22	3:45-4 p. m.	[1] 20	1	375,000	Wind	4 persons injured; loss to crops, $125,000; property damaged, $250,000. In Greater Little Rock, alone, property damage was estimated at $200,000. Length of path about 45 miles.

[1] Miles instead of yards.

[2] From press reports.

TABLE 4.—*Severe local storms, May 1939*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Lonoke County, Ark.	22	3:45–4:15 p. m.		1	175,000	Wind	5 persons injured. Property damage in England, Ark., alone, $50,000.
Fall River County, S. Dak.	22	6:15–7 p. m.	[1] 6		2,000	Heavy hail	Buildings damaged; $500 loss in Alfalfa; 75 lambs killed.
Martin, S. Dak.	22	9–9:30 p. m.			15,000	do	Property damaged; path narrow and 10 miles long.
Pine Ridge, S. Dak., 25 miles north.	22		50	1	2,500	Tornado	Property damaged; 1 person injured; path 440 yards long.
Meade County, S. Dak.	22–23	P. m.			6,500	Heavy rain	Numerous small dams washed out; fences wrecked; a 50-foot bridge destroyed.
Franklin, N. Y.	23	6 p. m.	55	1	20,000	Tornado	5 persons injured; gasoline station, several cabins, barns, and sheds destroyed. Many large trees uprooted blocking highways; telephone and power lines damaged; path 2 miles long.
Osborne, Kans.	23	7–7:30 p. m.	[1] 5		6,000	Wind	Property damaged; path 40 miles long.
Graham and Rooks Counties, Kans.	23	8:30–8:45 p. m.	[1] 20	0	7,500	Tornado	Tornado cloud not seen because of thick dust. Property damaged; path 25 miles long.
Norton and Logan, Kans., and vicinities.	23	9–9:30 p. m.	[1] 2		3,000	Wind	Property damaged; path 30 miles long.
Colorado	23					Wind and dust	Dust covered almost the entire State, continuing throughout most of the day. Visibility reduced to 100 feet.
Mora, Minn., and vicinity	23–24	P. m., 23d–a. m., 24th.				Electrical	Barn, silo, and 70 tons of hay burned; 10 cows killed.
Minneapolis and St. Paul, Minn.	24	1:20–5:32 a. m.				do	8 buildings damaged by lightning.
Itta Bena, Miss.	24	11 a. m.	17	0	800	Tornado and hail	Property damaged; path 880 yards long.
Boone County, Ark.	24	3 p. m.			5,000	Wind	Crop loss, $1,000; property damage, $4,000.
Pocahontas, Ark., vicinity of.	24	4 p. m.			9,000	Thundersquall and heavy hail.	House destroyed by lightning; damage to property, trees, and shrubs. Loss to crops, $3,000; property damage, $6,000.
Beardsley, Minn., and vicinity.	24	7–8:35 p. m.	[1] 23			Thunderstorm and hail.	Severe thunderstorm; hail caused small damage to gardens; windows broken. Storm moved from southwest to northeast over a path 40 miles long.
Hay Springs, Nebr.	24	9 p. m.	[1] 1		2,000	Hail	Damage to automobile tops and roofs.
Doniphan County, Kans.	25	8:30 a. m.	880	0	300	Tornado	Storm originated 2½ miles west of White Cloud, ending near the Nebraska line. Damage to farm property. Path 3½ miles long.
Minneapolis, Minn.	25	3–5:20 p. m.				Electrical and wind.	Washington Avenue Bridge, several houses and buildings struck by lightning. Many wires down; trees uprooted; railroad watchman's tower toppled.
Kenton, Okla.	25	3:14 – 3:21 p. m.	[1] 3		4,125	Heavy hail	$3,000 loss to alfalfa, gardens, and other crops; property damage, $1,125; path 6 miles long.
Clinton, Iowa, and vicinity.	25	4:45 p. m.	100	0	2,600	Tornado	Damage to buildings; boathouse collapsed; trees and branches twisted off. Heavy rain of short duration.
Jennings and Oronoque, Kans., and vicinities.	26	4–4:30 p. m.	2,640		20,000	Heavy hail	Loss to crops; damage to property; path 15 miles long.
Michigan, southwestern lower portion.	26	4:30 p. m.			5,000	Wind, rain, and hail.	Telephone, power lines, trees, and barns blown down, the area being without communication until 9 p. m. On a farm a granary, chicken house, and chimney were destroyed. Windows broken and porches smashed in several farm homes between Glenn and Pullman on the Bravo road which was blocked by fallen trees.
Green and Clay Counties, Ind.	26	P. m.			15,000	Wind	Buildings damaged; trees and poles down.
Jewell, Iowa, vicinity of.	27	5 p. m.			3,000	Electrical	Barn and granary with contents destroyed by fire.
Detroit, Mich., and vicinity.	27	5:30 p. m.				Thunderstorm	Streets flooded; car service interrupted; power plant struck by lightning. In some sections of Ecorse, water stood 2 feet deep in streets, flooding cellars; motors stalled; much damage to fruit.
Karnack, Tex.	27	6:30 p. m.	220			Wind	4 buildings unroofed; trees down.
Abilene, Tex.	27	11:50 p. m.				do	Several thousand dollars' damage to buildings, windows, signs, and awnings.
Merango, Ill.	27				3,000	Electrical	Barn filled with hay burned.
Little York and Preble, N. Y.	27	P. m.				Thundersquall	Several silos demolished; roofs damaged; many trees uprooted; much damage to telephone and power lines.
San Jon, N. Mex.	28		[1] 1		500	Hail	Cotton to be replanted.
La Mesa, N. Mex.	29	9 p. m.	[1] 1		8,000	do	Loss in cotton crop.

[1] Miles instead of yards.

U. S. GOVERNMENT PRINTING OFFICE: 1939

Chart I. Departure (°F.) of the Mean Temperature from the Normal, and Wind Roses for Selected Stations, May 1939

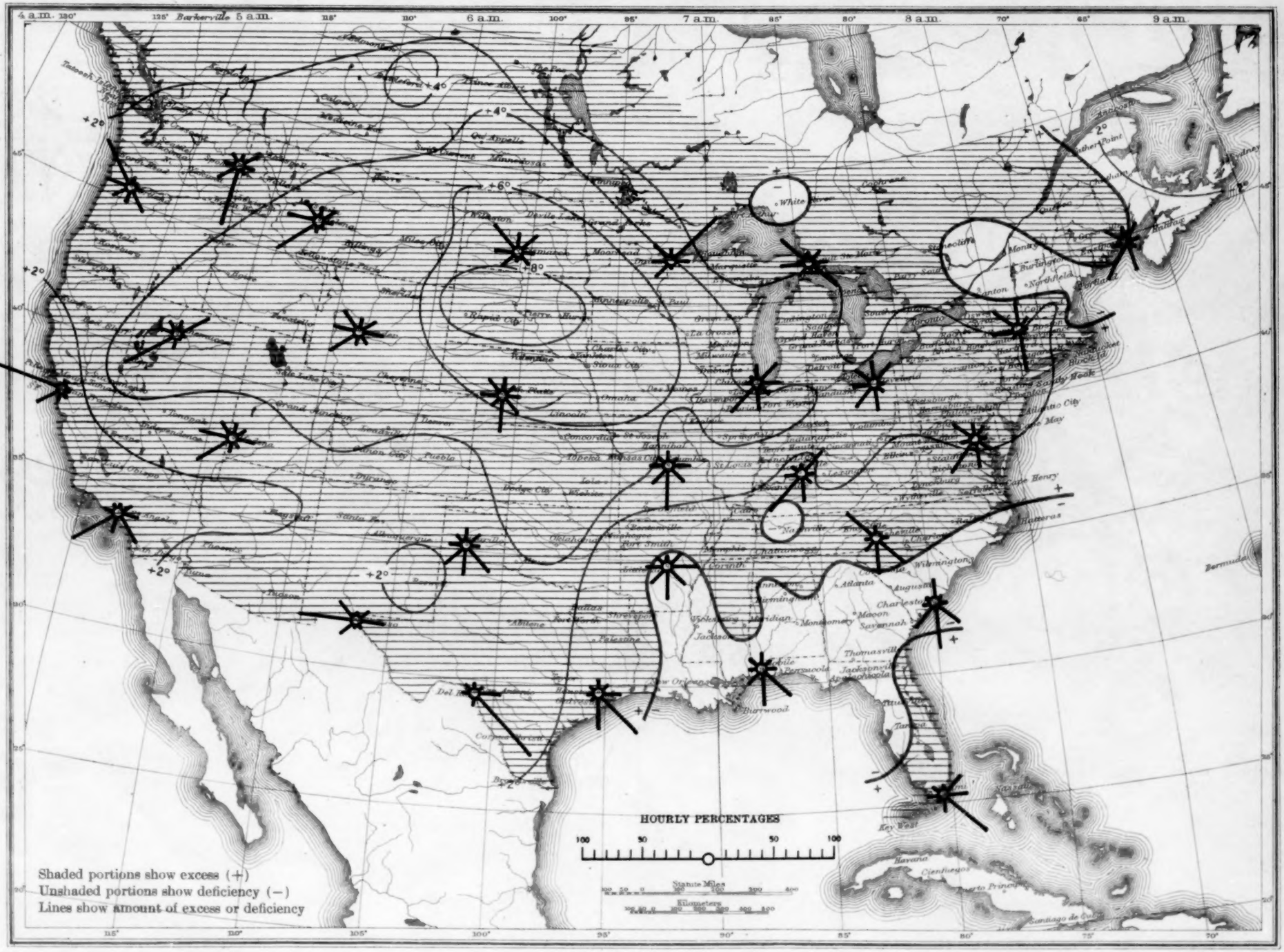
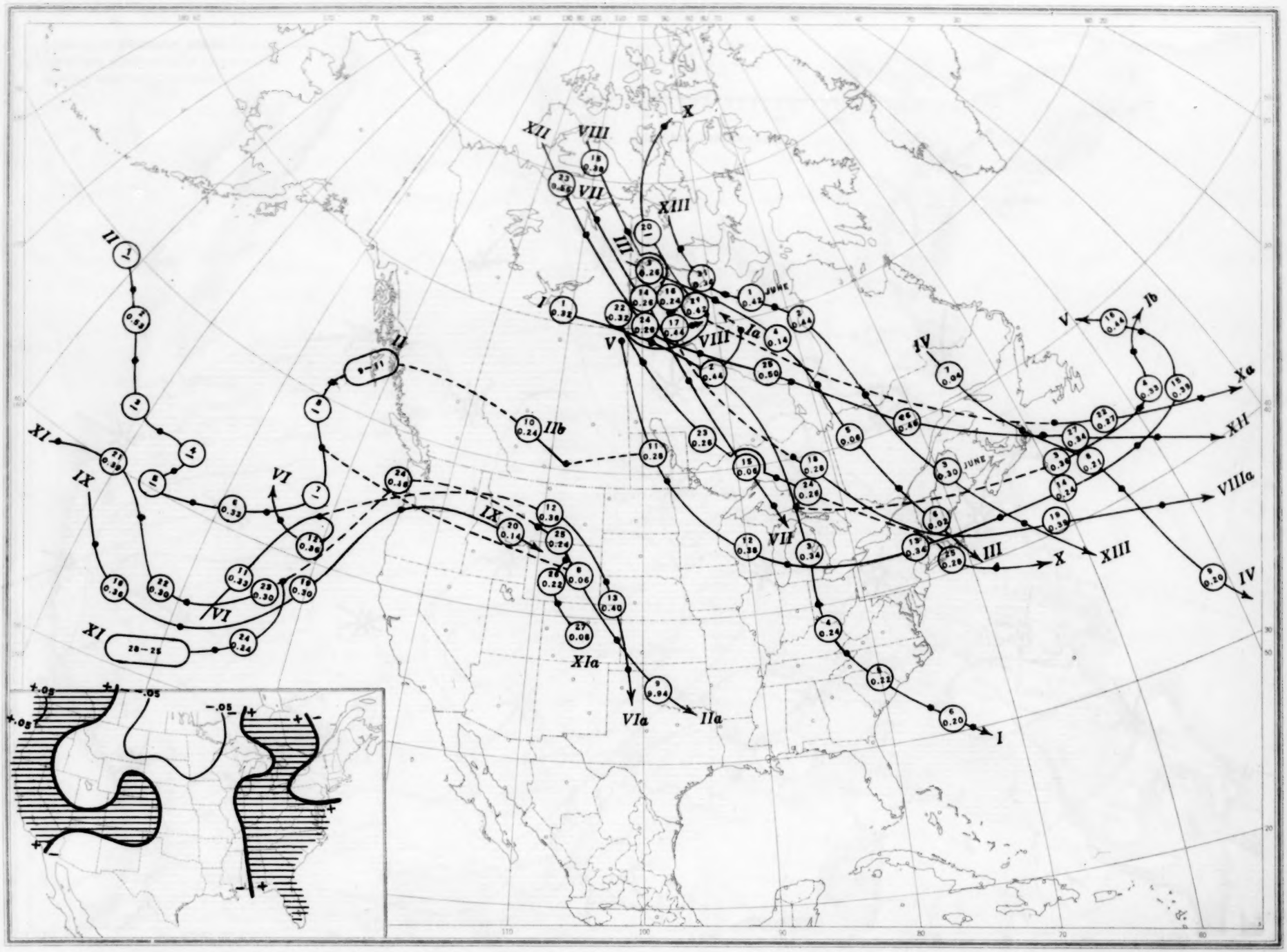


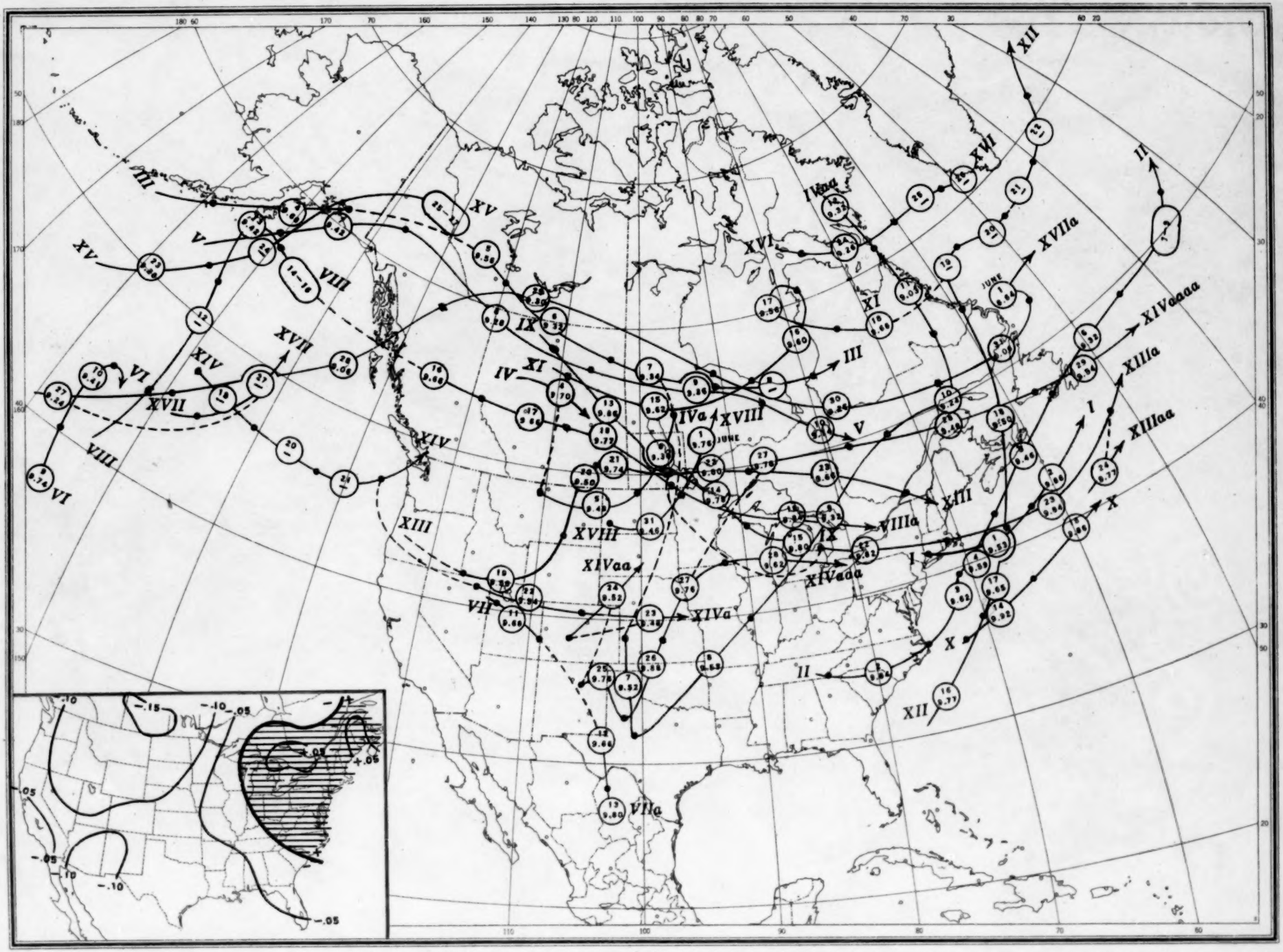
Chart II. Tracks of Centers of Anticyclones, May 1939. (Inset) Departure of Monthly Mean Pressure from Normal



Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, May 1939. (Inset) Change in Mean Pressure from Preceding Month



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, May 1939

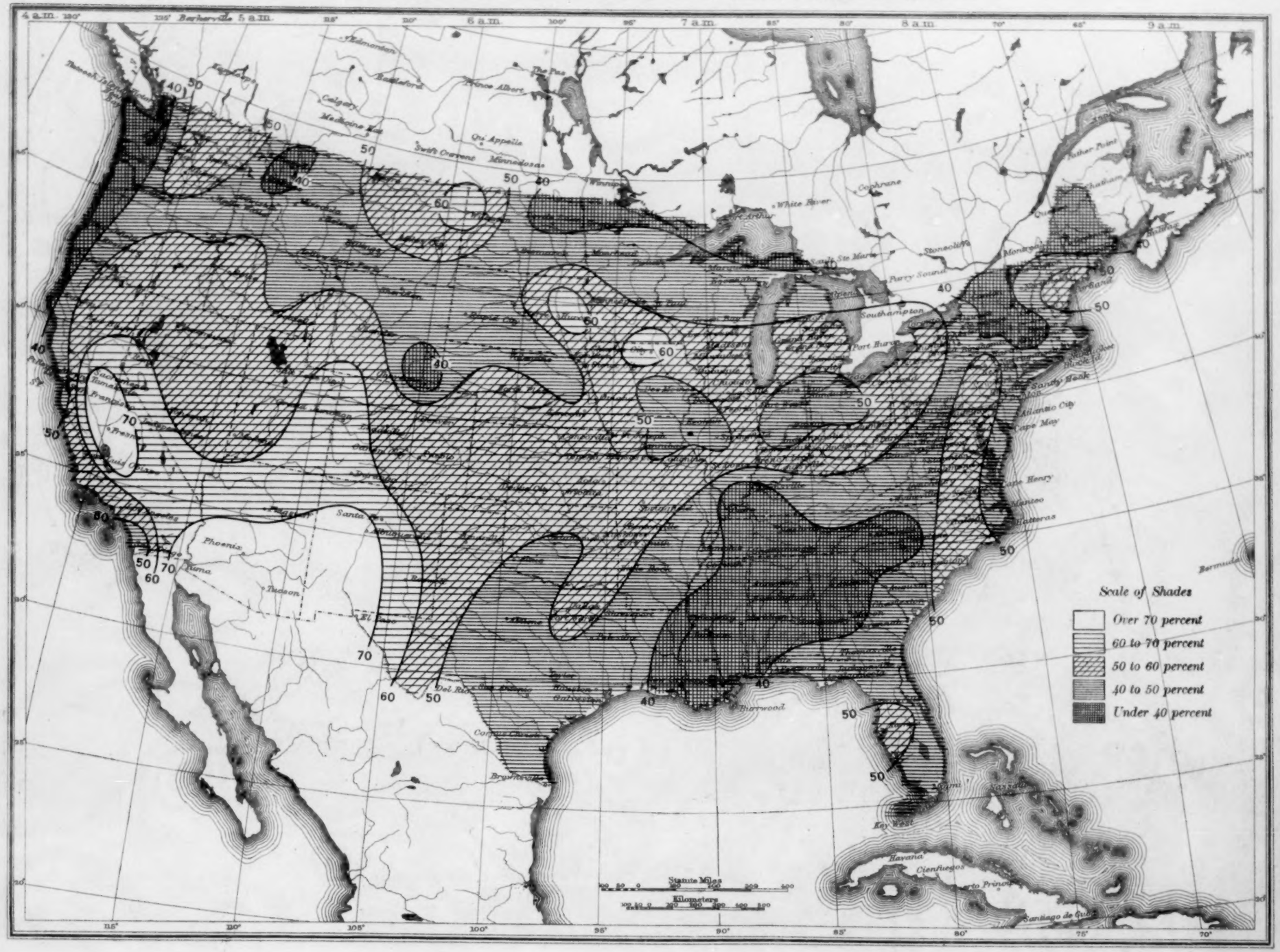


Chart V. Total Precipitation, Inches, May 1939. (Inset) **Departure of Precipitation from Normal**

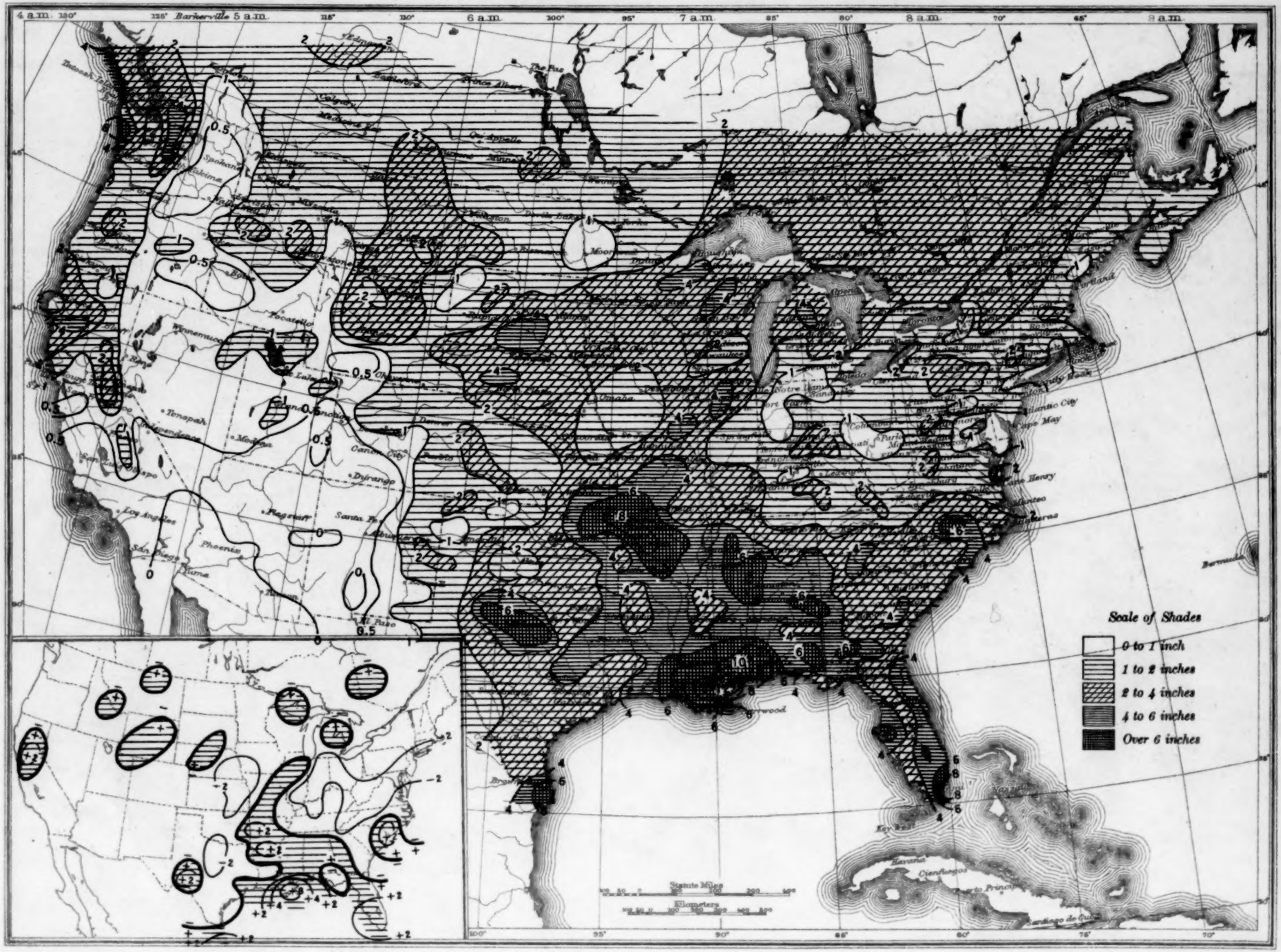


Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, May 1939

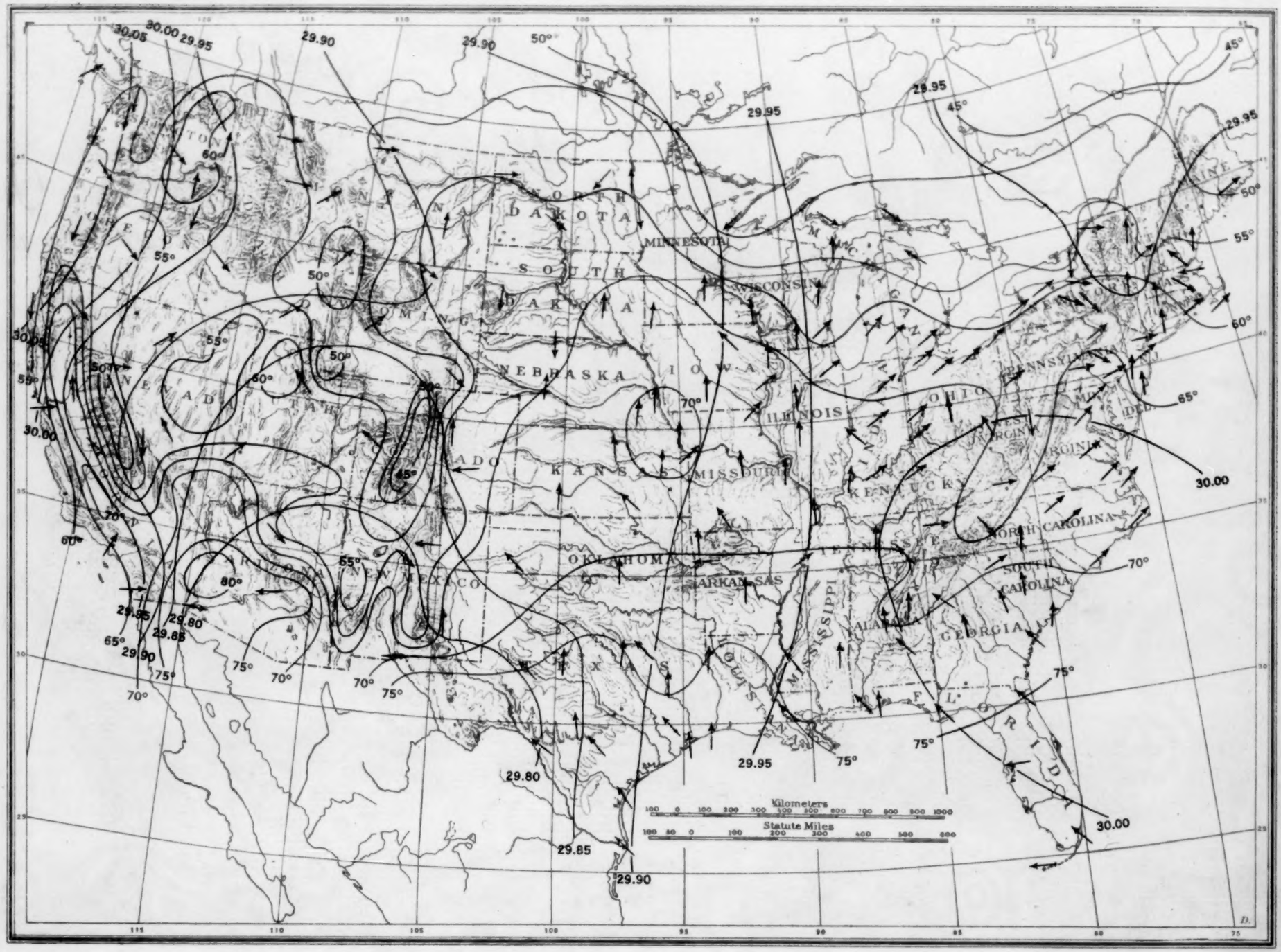


Chart VIII. Isobars (mb) for 1,524 Meters (5,000 ft.) and Isotherms (°C.) and Resultant Winds for 1,500 Meters (m. s. l.) May 1939

Chart IX. Isobars (mb) Isotherms (°C.) and Resultant Winds for 3,000 Meters (m. s. l.) May 1939

Chart X. Isobars (mb) Isotherms (°C.) and Resultant Winds for 4,000 Meters (m. s. l.) May 1939

Chart XI. Isobars (mb) Isotherms (°C.) and Resultant Winds for 5,000 Meters (m. s. l.) May 1939

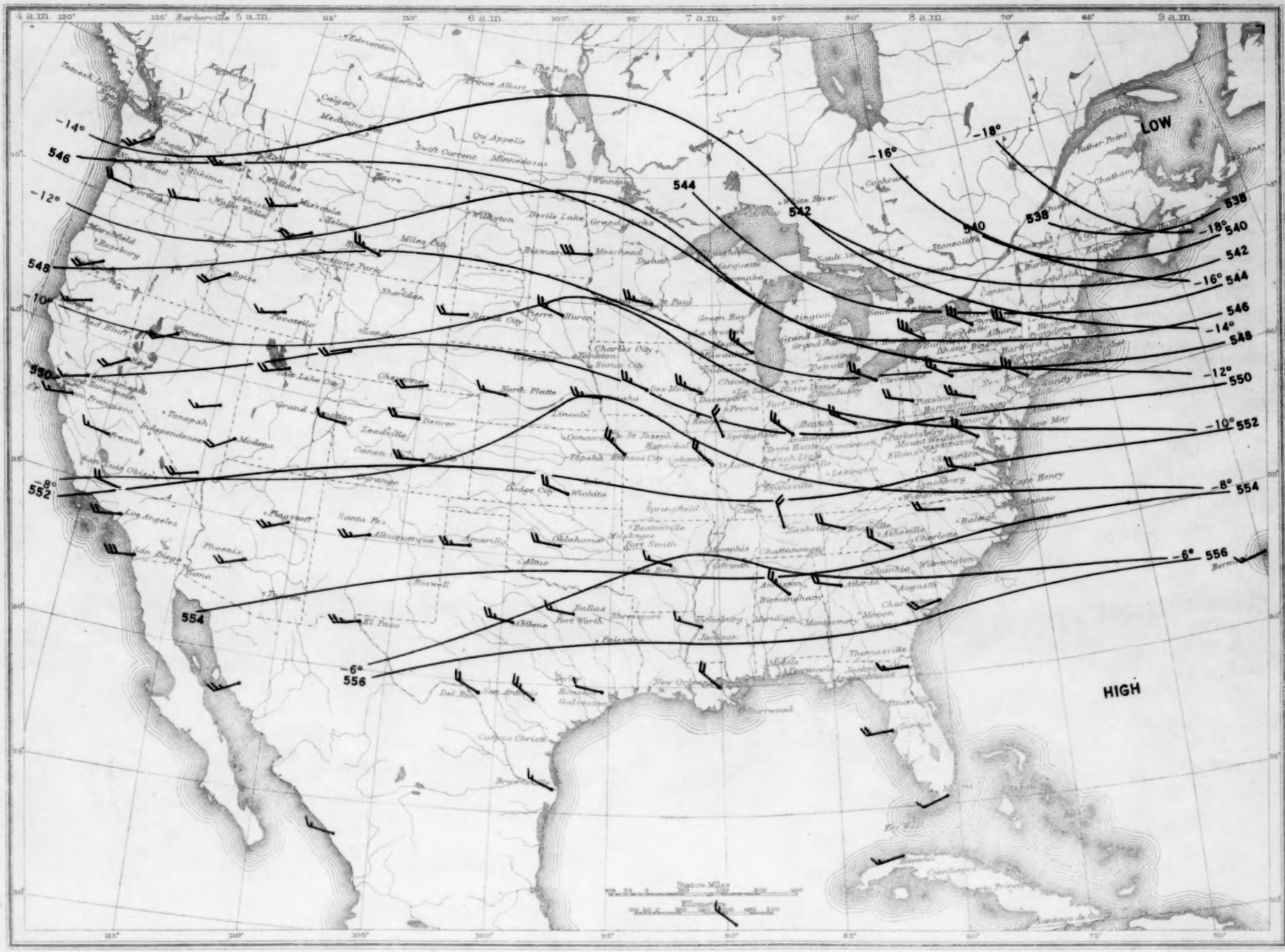
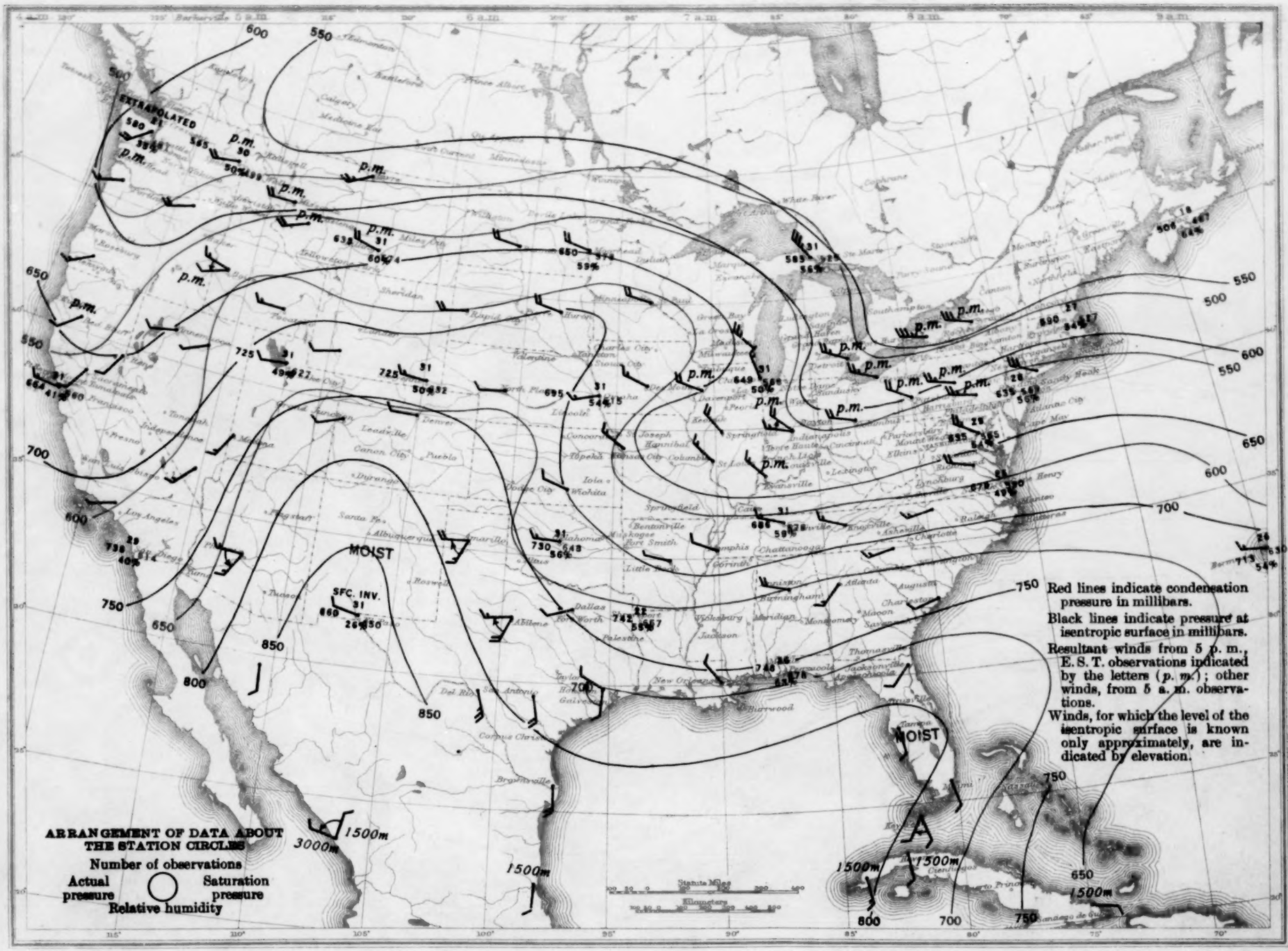


Chart XII. Mean Isentropic Chart, May 1939 (Potential Temperature 307° A.)


EXTRAPOLATED
MOIST
SFC. INV.
MOIST
p.m.
1500m
3000m
1500m
1500m
1500m
1500m
Red lines indicate condensation pressure in millibars.
Black lines indicate pressure at isentropic surface in millibars.
Resultant winds from 5 p. m., E. S. T. observations indicated by the letters (p. m.); other winds, from 5 a. m. observations.
Winds, for which the level of the isentropic surface is known only approximately, are indicated by elevation.
ARRANGEMENT OF DATA ABOUT THE STATION CIRCLES
Number of observations
Actual pressure
Saturation pressure
Relative humidity
Statute Miles
Kilometers